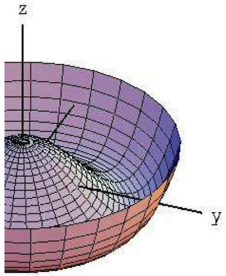
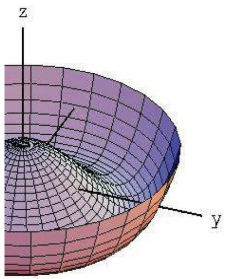


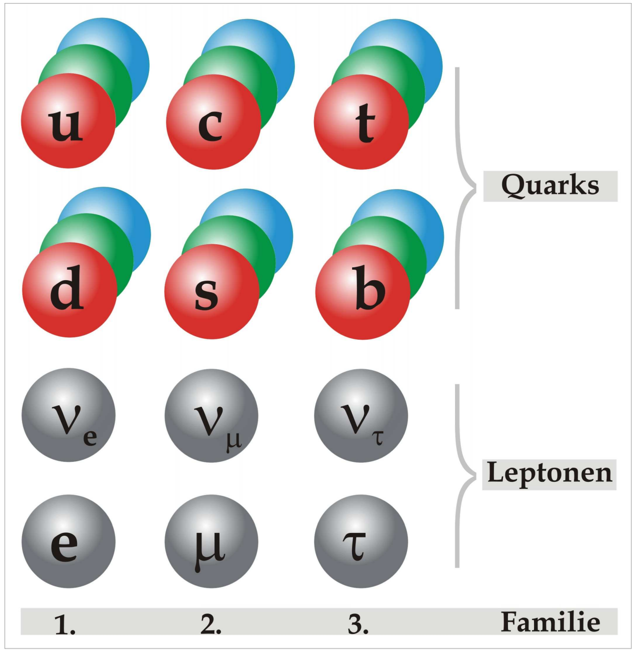
The International Linear Collider
A precision instrument for the Higgs Boson

K. Desch • Universität Bonn • 11/01/2007 • LTP/PSI Colloquium

1. A massive problem
2. The LEP heritage
3. Years of Decision: Higgs at Tevatron and LHC
4. Higgs at the ILC
5. Detectors for the ILC
6. ILC project



Microphysics today – beautiful but puzzling



Beautiful:

Consistent description of all microscopic matter + forces (except gravity)

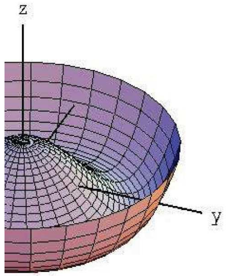
Based on symmetry principle (local gauge symmetry)

All matter + force particles are experimentally observed!

Puzzling:

1. Origin of particle masses

2. Hierarchy, Unification,
   Origin of Flavour,
   Dark Matter and all that…



A Massive Problem

Massive vector bosons violate gauge invariance

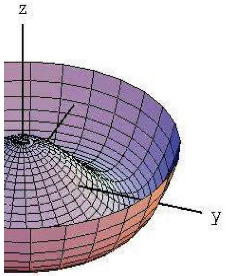
wave equation $$\left(\Box + M^2\right) W^\nu - \partial^\nu \partial_\mu W^\mu = j^\nu$$

gauge transformation $$W^\nu \rightarrow W^\nu - \partial^\nu \chi$$

yields additional $$-M^2 \partial^\nu \chi$$

→ theory not renormalizable!
→ at best low energy effective theory
could be…

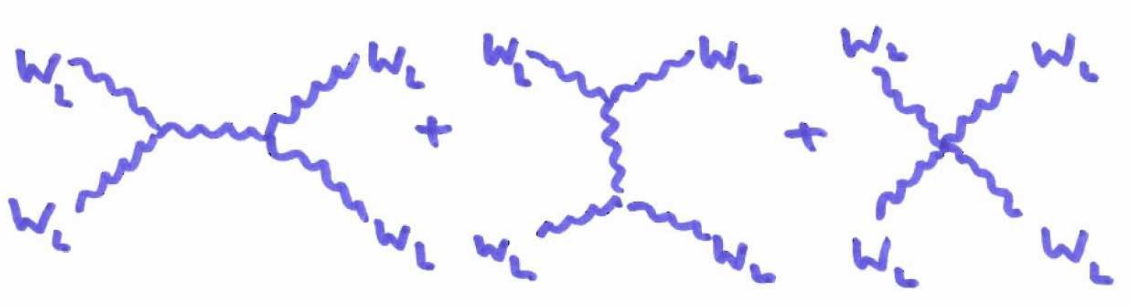
consequence: Standard Model breaks down at ~1 TeV



consequences…

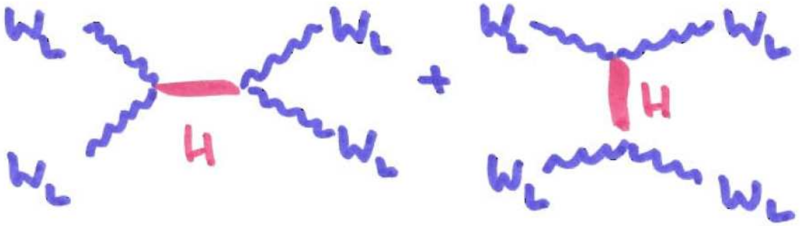
Polarization vector for longitundinal W bosons

$$\varepsilon^{\mu}_{\text{long}}(p) = \frac{1}{M_W}(E,0,0,p) \sim E$$

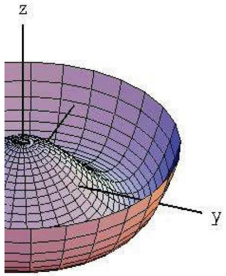


diverges for √s → ∞, violates unitarity at √s ≈ 1.2 TeV

divergency can be compensated by new scalar particles
with coupling ~ mass



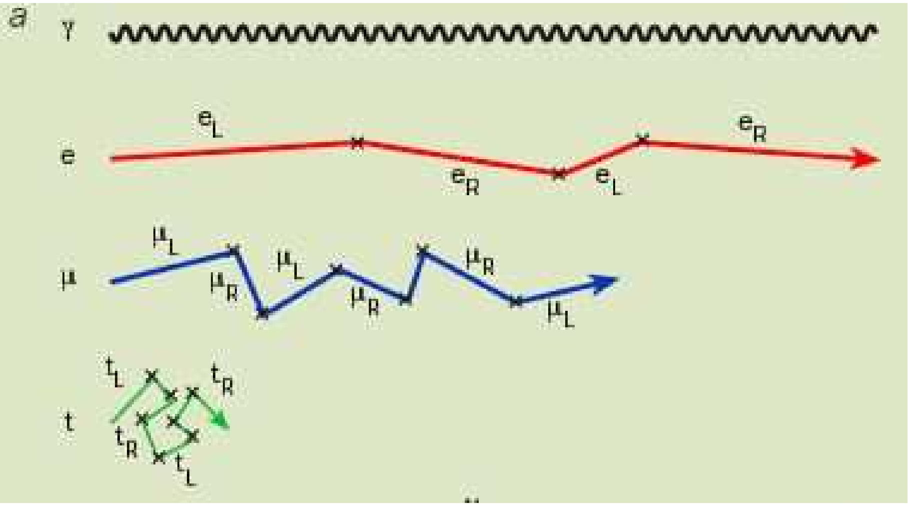
The Higgs boson



The Higgs mechanism

Paradigm:
All elementary particles
are massless!

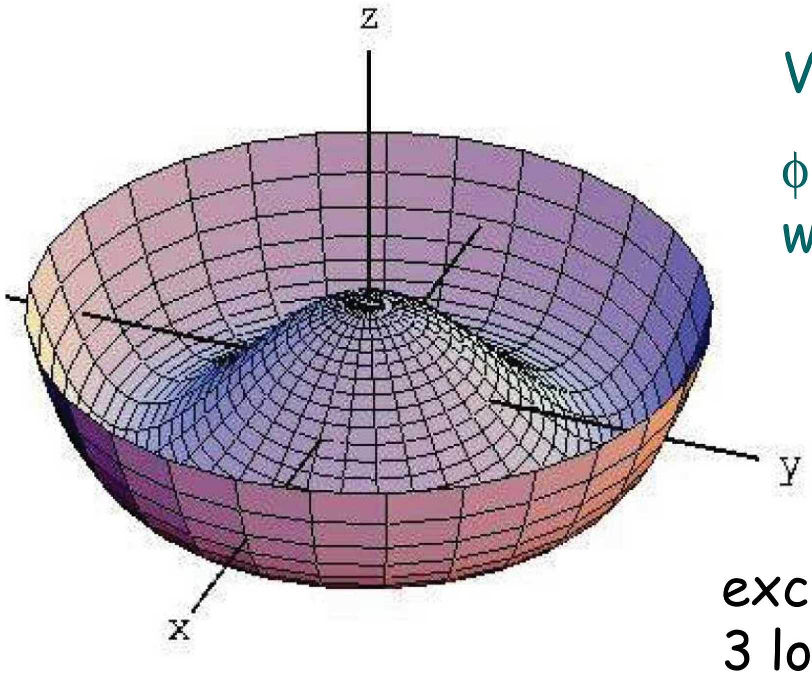
➪ gauge principle works
➪ renormalizable theory
(finite cross sections)



Interaction of particles with Higgs field makes them act as if they had mass

The Higgs Mechanism in the SM

Adding a field with $\langle\Phi\rangle_0 \neq 0$ in a gauge-invariant way is non-trivial – requires field with self interaction

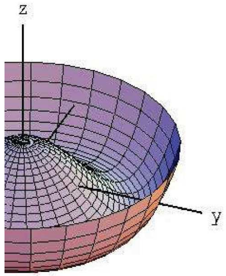


$V = -\mu^2 |\phi^+\phi| + \lambda |\phi^+\phi|^2$

ϕ: complex scalar doublet of weak isospin

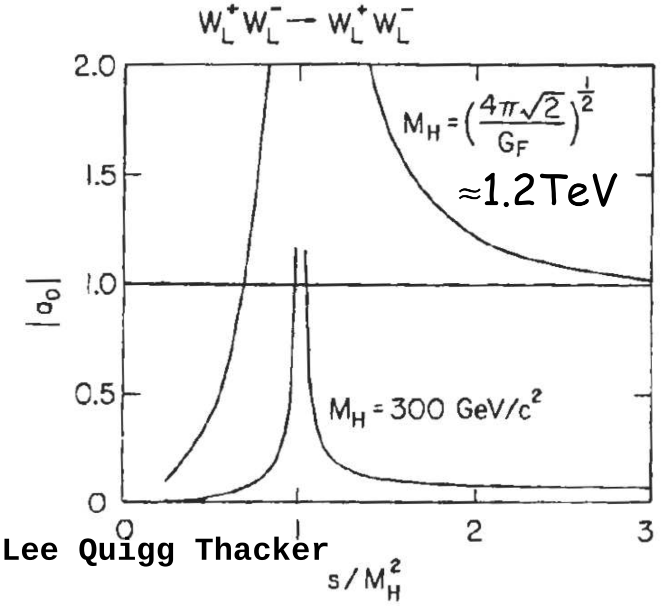
$$\phi = \begin{pmatrix} \phi^+ \\ \phi^o \end{pmatrix} \quad \langle\phi\rangle_o = \begin{pmatrix} o \\ \upsilon \end{pmatrix}$$

excitations of ϕ:
3 longitudinal d.o.f's of gauge bosons
1 Higgs boson, $m_H=\mu$
only unknown in Standard Model



The mass of the Higgs (theory)

If the Higgs is too heavy, it comes too late to save us

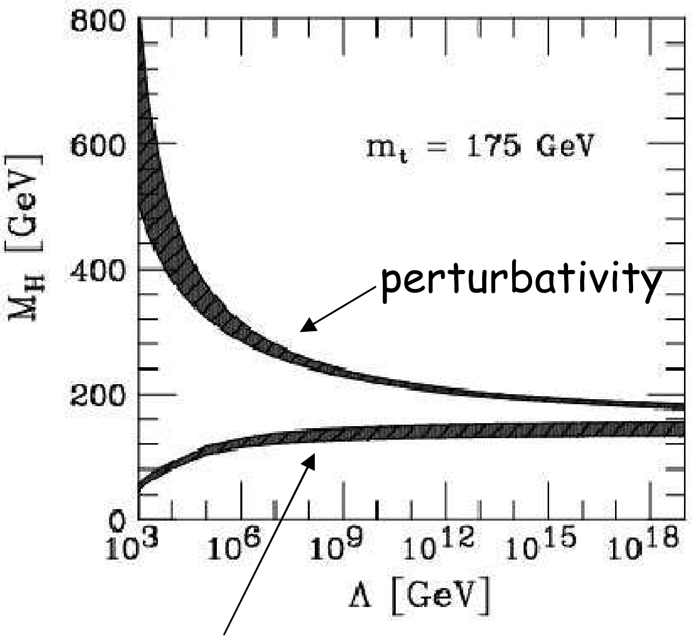


Lee Quigg Thacker

FIG. 6. Sketch of the energy dependence of the $J=0$ partial-wave amplitude for elastic scattering of longitudinally polarized W bosons for two choices of the Higgs-boson mass. For $M_H > (4\pi\sqrt{2}/G_F)^{1/2}$ the partial-wave unitarity bound $|a_0| \le 1$ is violated for $s > M_H^2$.

a_0 = scattering amplitude (J=0)
unitarity: $|a_0| < 1$

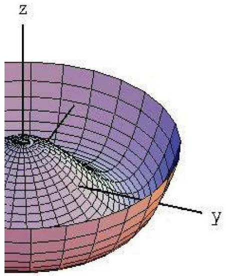
stronger limits from requirement of perturbativity and vacuum stability



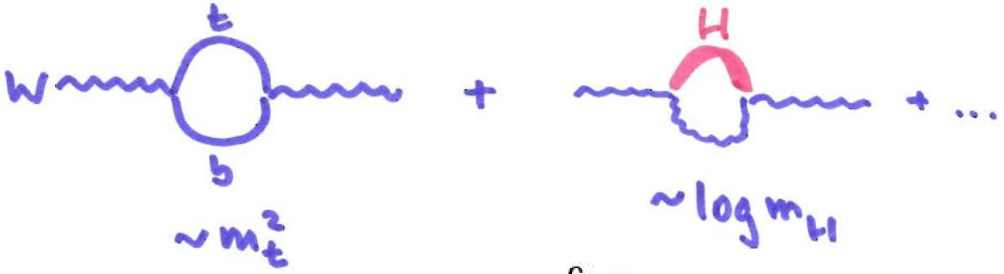
perturbativity

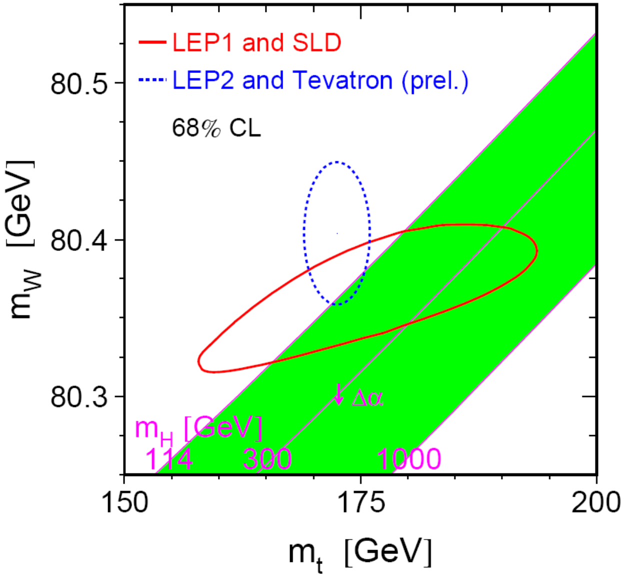
vacuum stability

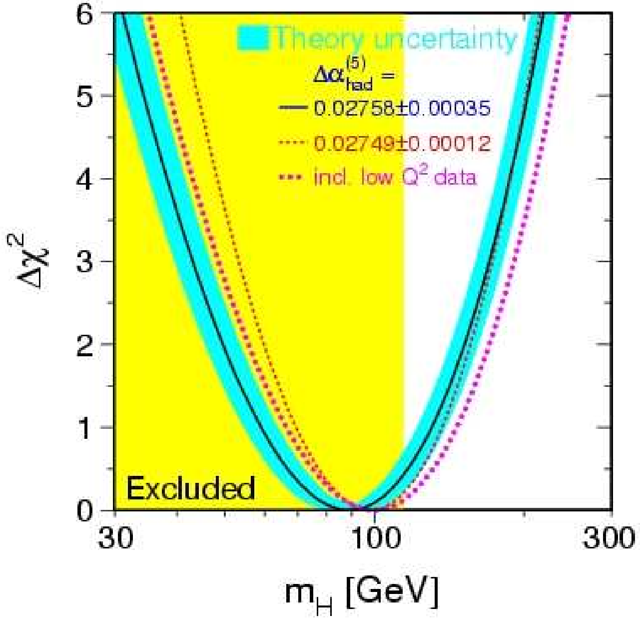
Riesselmann



The mass of the Higgs (Experiment)



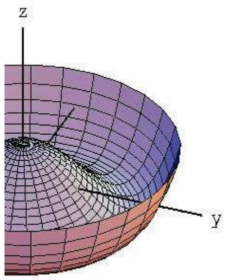




LEP-EWWG

The SM works:
direct and indirect masses
agree

m_H =91 +45 -32 GeV
m_H < 186 GeV @ 95%CL
within the SM



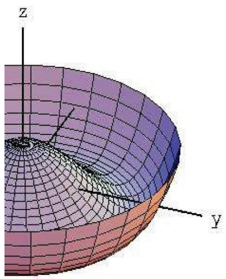
Alternatives

In spite of the excellent agreement of the data with the SM Higgs hypothesis there is no guarantee for its existence

The discovery of the SM Higgs Boson at Tevatron or LHC would be a major breakthrough!!!

Route 1: no Higgs mechanism
→ requires new interaction at the TeV scale
Technicolor, Higgsless Models, …
in general in conflict with precision data, but…

Route 2: Higgs mechanism, but more baroque realisation
- two doublets (minimal supersymmetry)
- additional Singletts (NMSSM, „Higgs continuum")
- triplets (LR symmetry)
- …

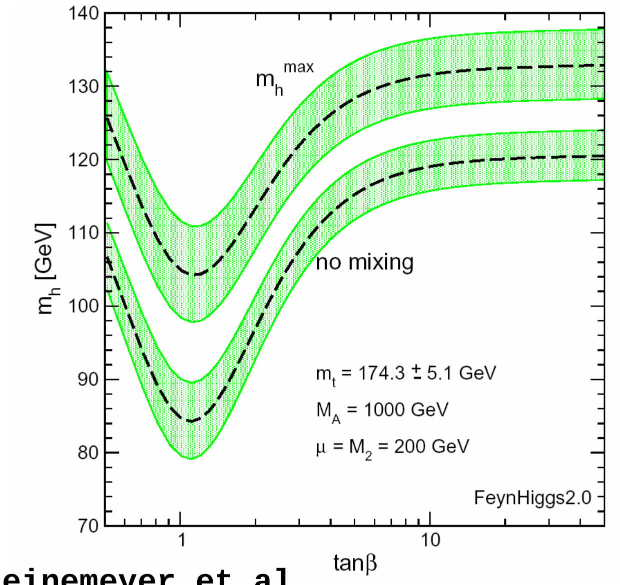


Higgs bosons in minimal Supersymmetry (MSSM)

SM Higgs mass undergoes large radiative corrections
→ needs „finetuning", if SM is required to be valid up to high scales

Supersymmetry sloves this through ≈cancellations of corrections

Higgs sector needs to be extended:
at least 2 Higgs doublets with v.e.v.'s v_1 and v_2

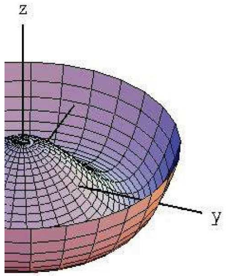


Heinemeyer et al

h,H	neutral, CP-even
A	neutral, CP-odd
$H^\pm$	charged

masses are predicted as a function of SUSY parameters
leading order: only m_A and $\tan\beta = v_2/v_1$
large corrections (top, stop)

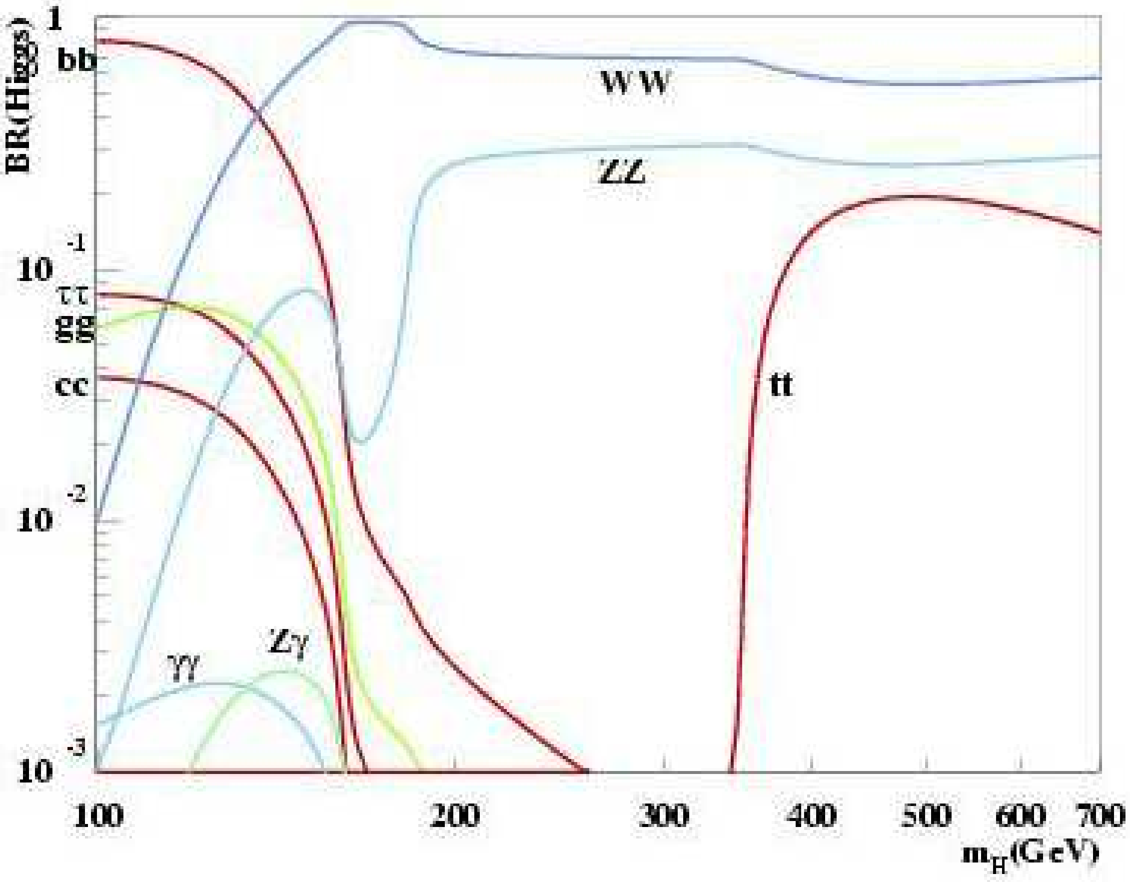
$m_h < 135$ GeV



Higgs decays in the Standard Model

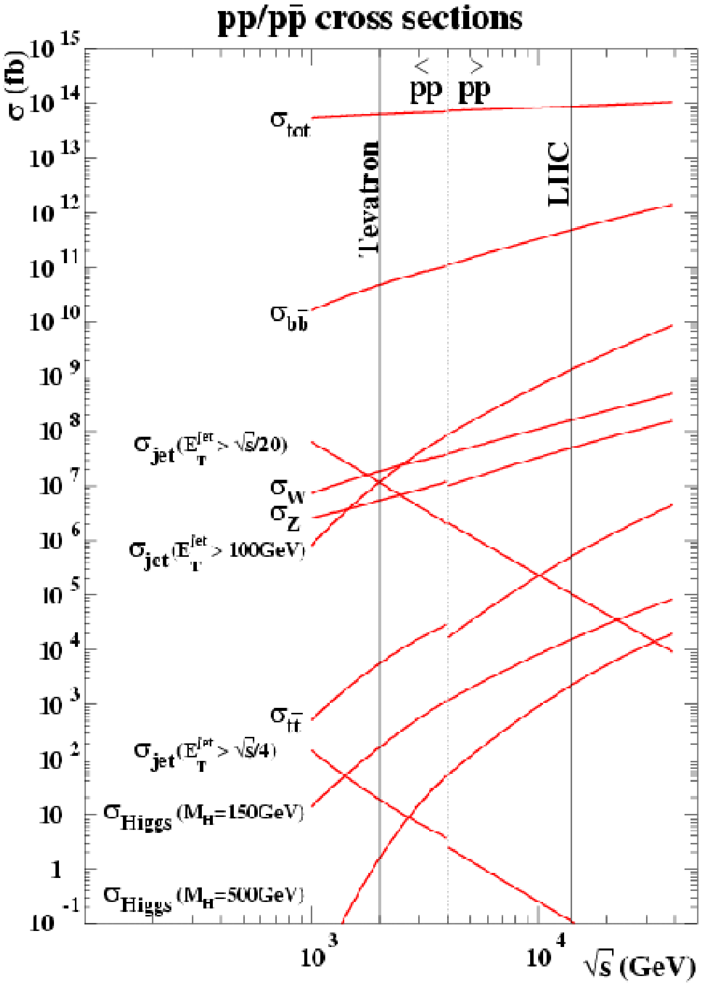
determined by Higgs coupling to mass

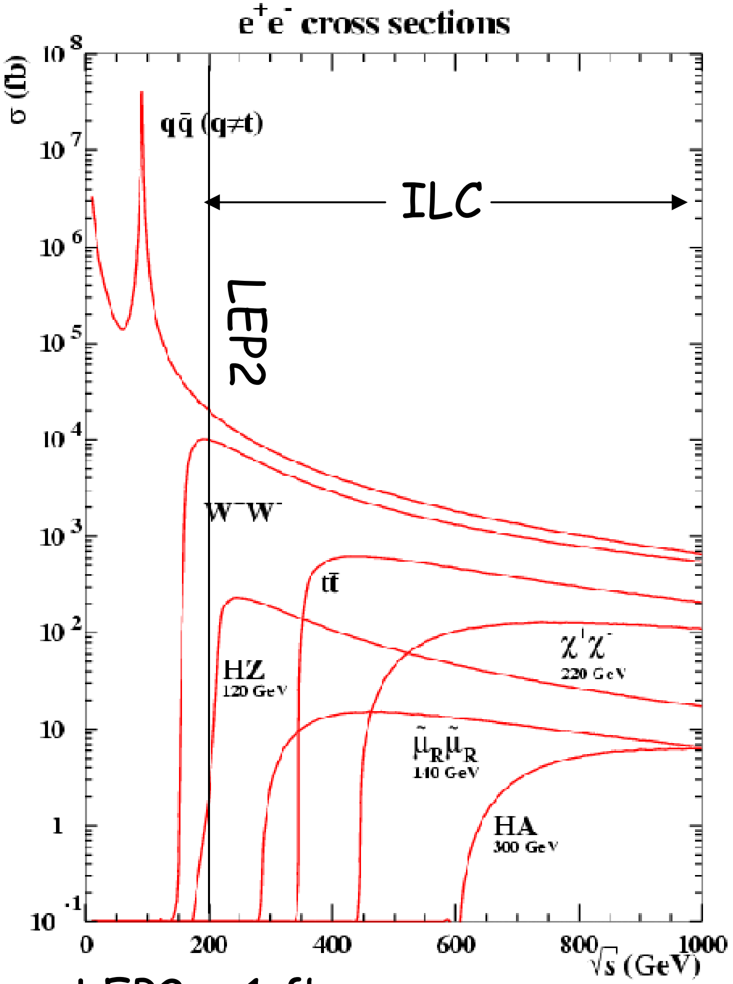
$g_{HVV} \sim M_V$ $g_{Hf} \sim M_f$



Spira et al

Higgs production



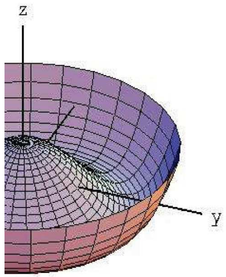


for m_H=120 GeV

Tevatron: ~700fb
LHC : ~30000fb
S/B ~ 10^{-12}

LEP2: ~1 fb
ILC: ~200 fb
S/B ~ 10^{-2}

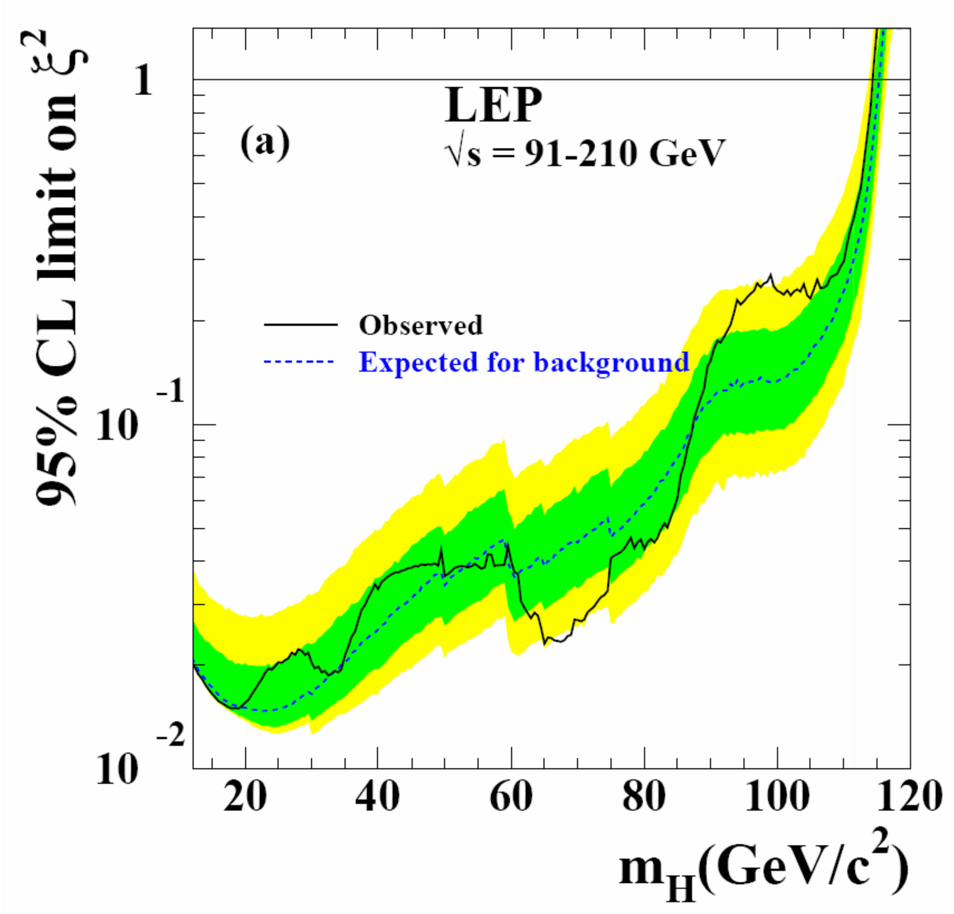
The LEP heritage

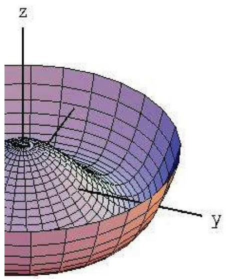


The LEP heritage: SM Higgs

SM Higgs excluded for $m_H < 114.4$ GeV (95%CL)

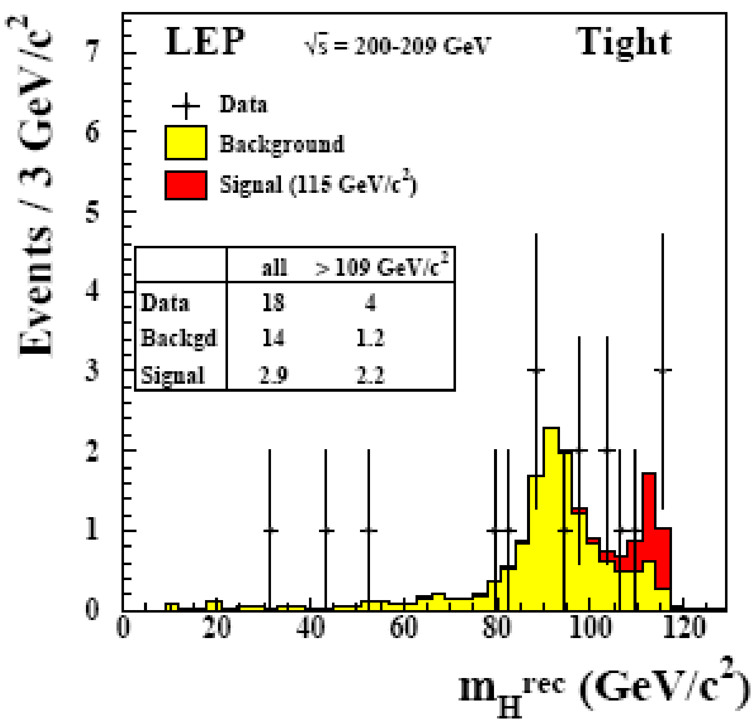
for model-builders: limits on g^2_{HZ}:



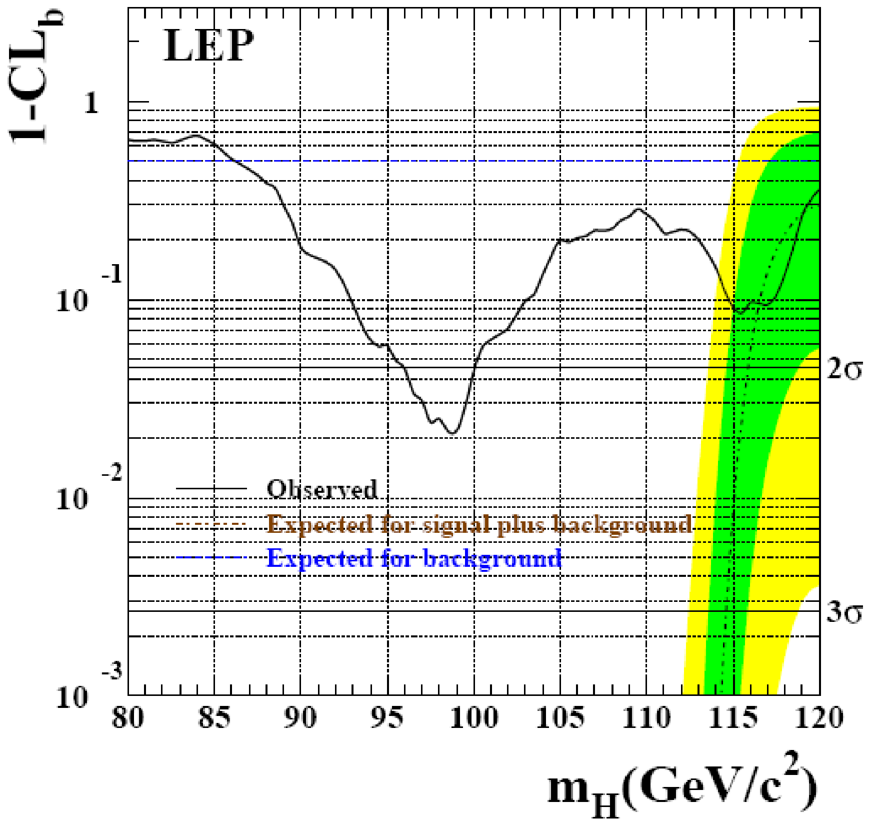


The LEP Heritage: SM Higgs

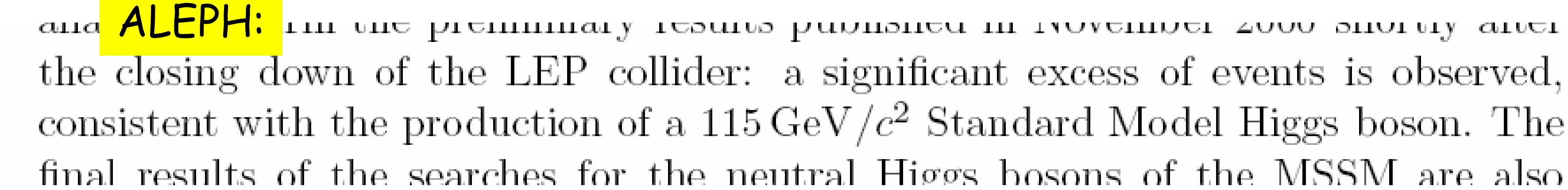
Slight excess at $m_H \approx 98$ GeV (2.3σ) and $m_H \approx 115$ GeV (1.7σ)



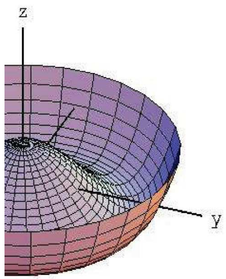
	all	> 109 GeV/c²
Data	18	4
Backgd	14	1.2
Signal	2.9	2.2



ALEPH:

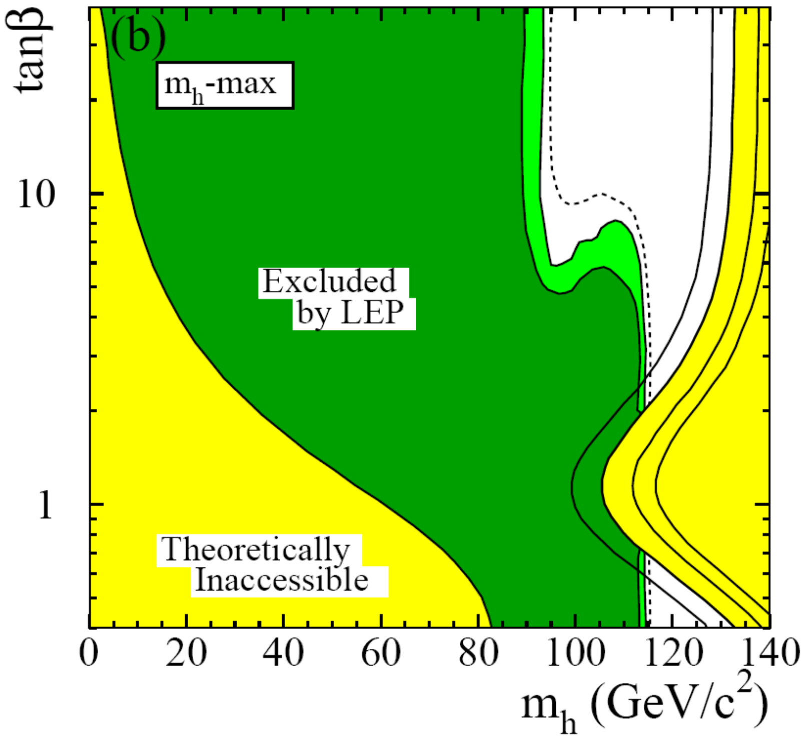


and in the preliminary results published in November 2000 shortly after the closing down of the LEP collider: a significant excess of events is observed, consistent with the production of a 115 GeV/c^2 Standard Model Higgs boson. The final results of the searches for the neutral Higgs bosons of the MSSM are also

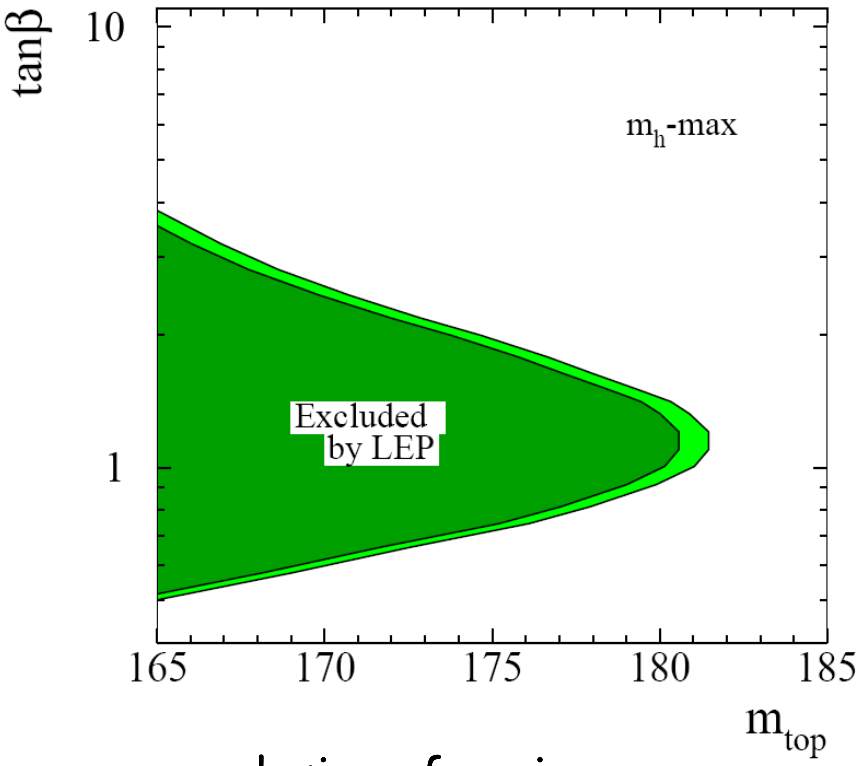


The LEP Heritage: MSSM Higgs

Final combination of neutral MSSM Higgs searches
published in 2006!   (warning for those who expect LHC papers in 08…)

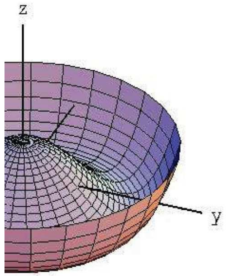


$m_{\text{top}} = 174.3\,\text{GeV}$



exclusion of region
in tanβ as function of m_{top}

m_h, m_A < 93 GeV @ 95%CL



The LEP heritage: exotics

Limits on a multitude of extended Higgs models

- charged Higgs Bosons
- doubly charged Higgs Bosons
- invisible Higgs decays
- fermiophobic Higgs Bosons (H→$\gamma\gamma$)

m >~ 100 GeV

- Higgs continuum

- decay-independent limit

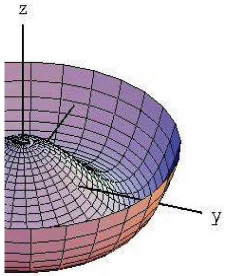
but:

not everything below 100 GeV is excluded!

- (very) light CP-odd Higgs →B-Fabriken?

- Higgs/Radion-mixing (Randall Sundrum model)

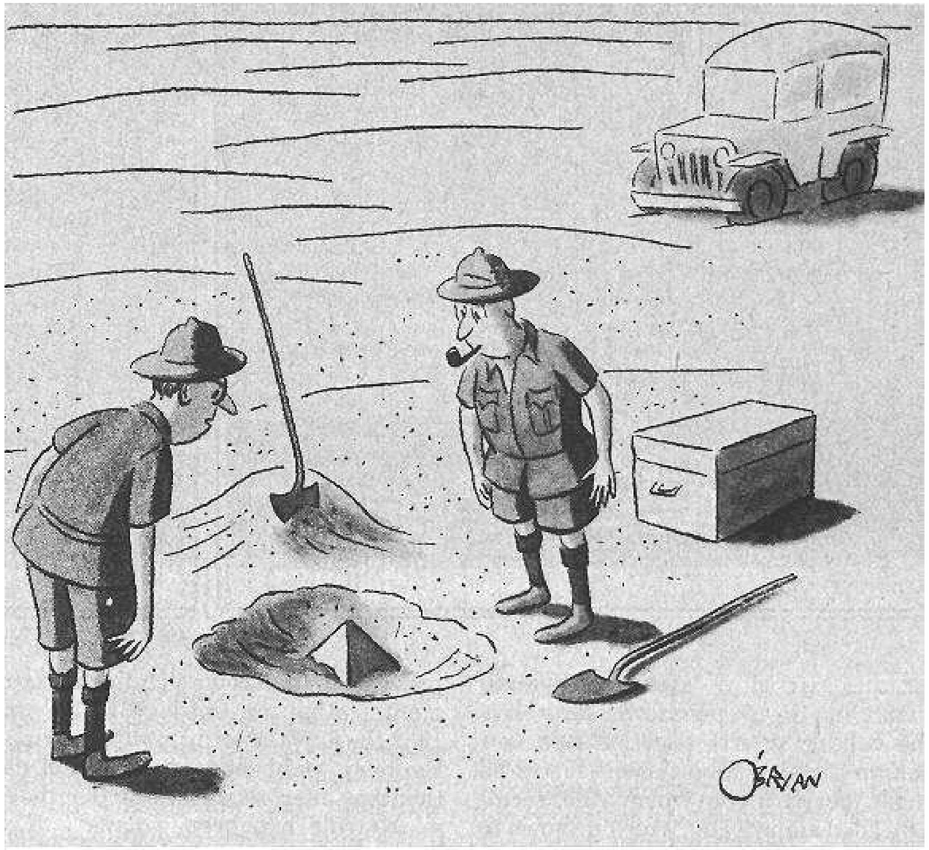
- MSSM with CP violation



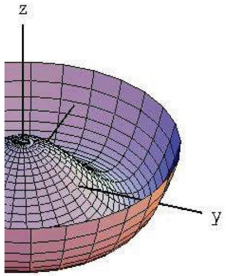
The decision years

Tevatron

LHC



"This could be the discovery of the century. Depending, of course, on how far down it goes."

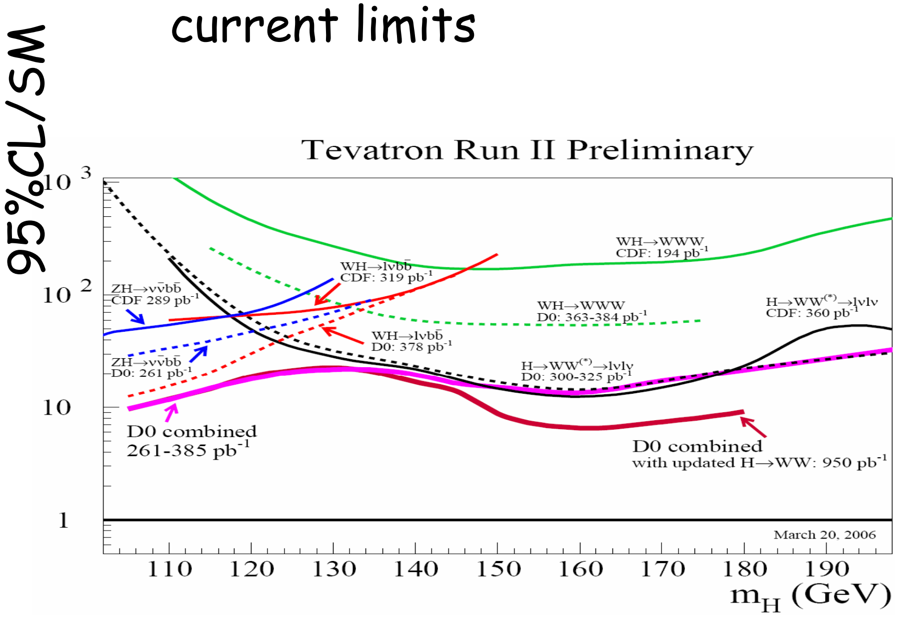


Higgs search at the Tevatron

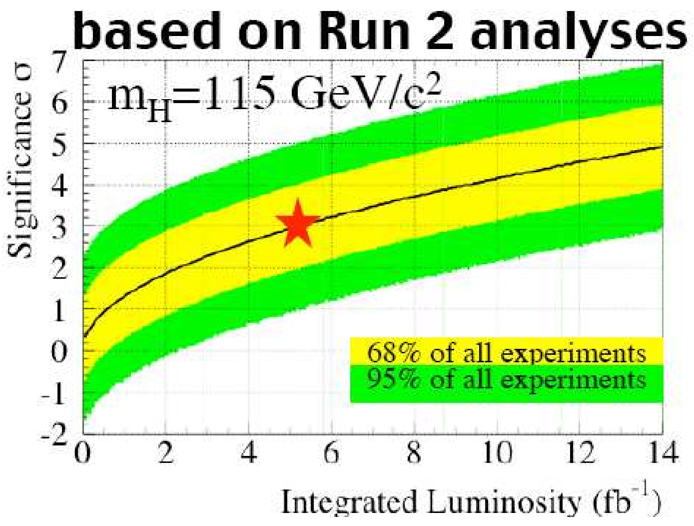
>1 fb^{-1}/Experiment recorded
if the SM is correct, 1000 Higgses already produced!

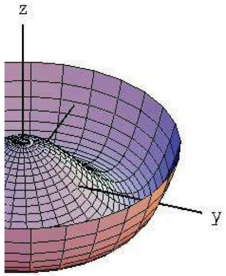
8 fb^{-1} expected until end 2009 ?

current limits

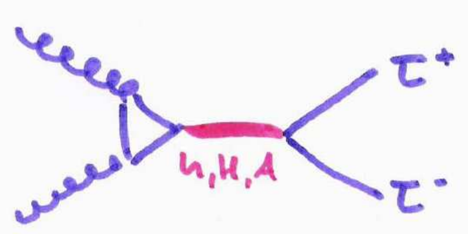


prospects

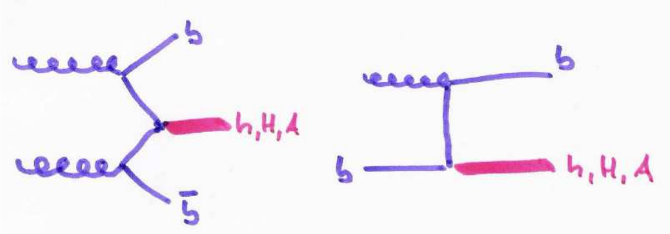


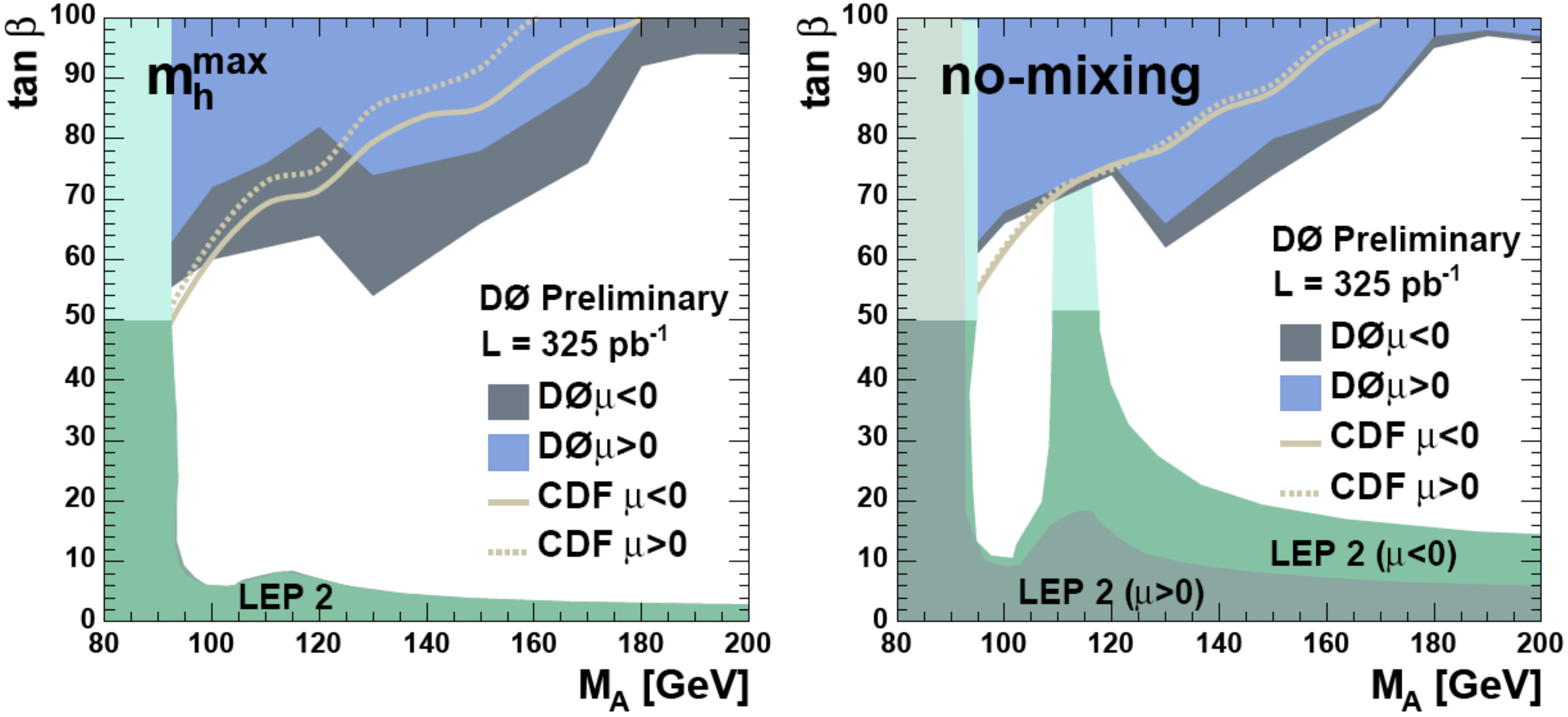


SUSY-Higgs at Tevatron



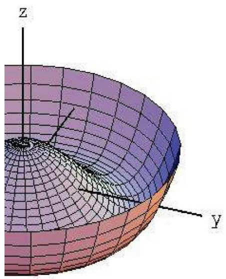
$\sigma \sim \tan^2\beta$



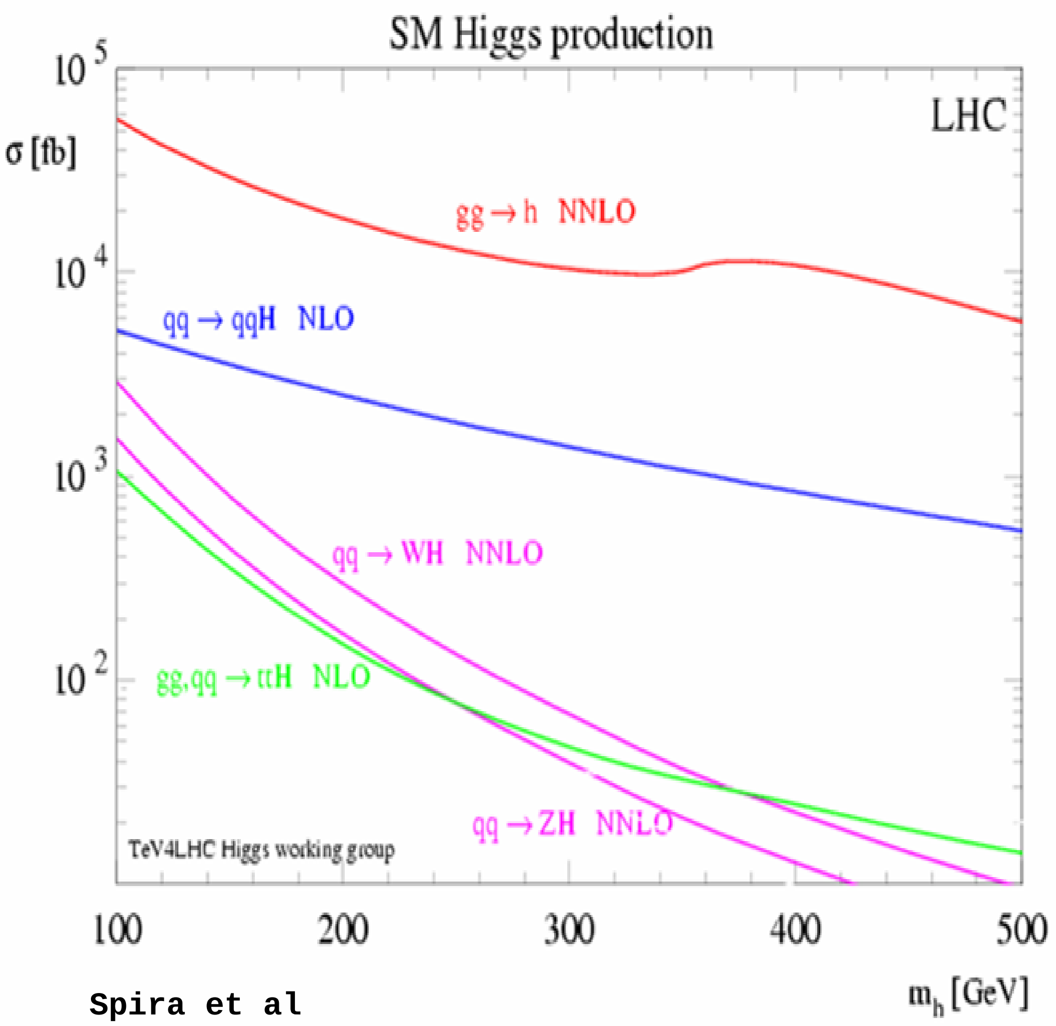


searches are beginning to scratch the physically sensible region…

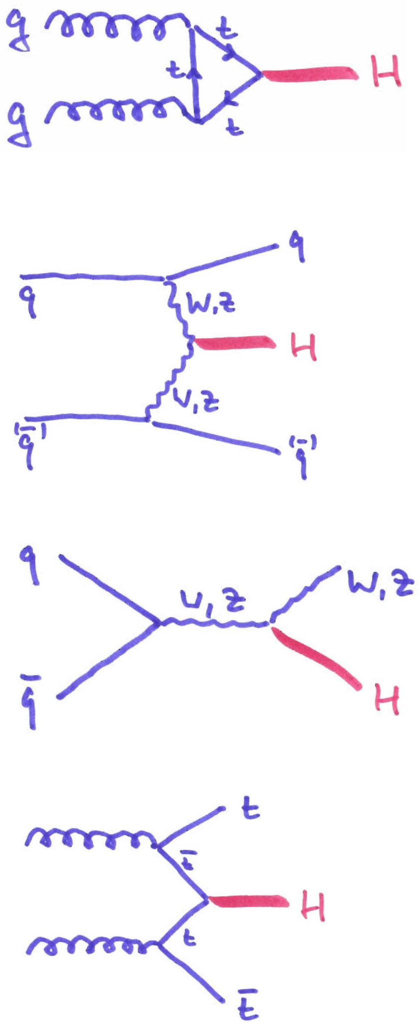
The LHC is a reality!

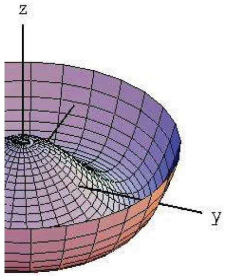


Higgs production at LHC

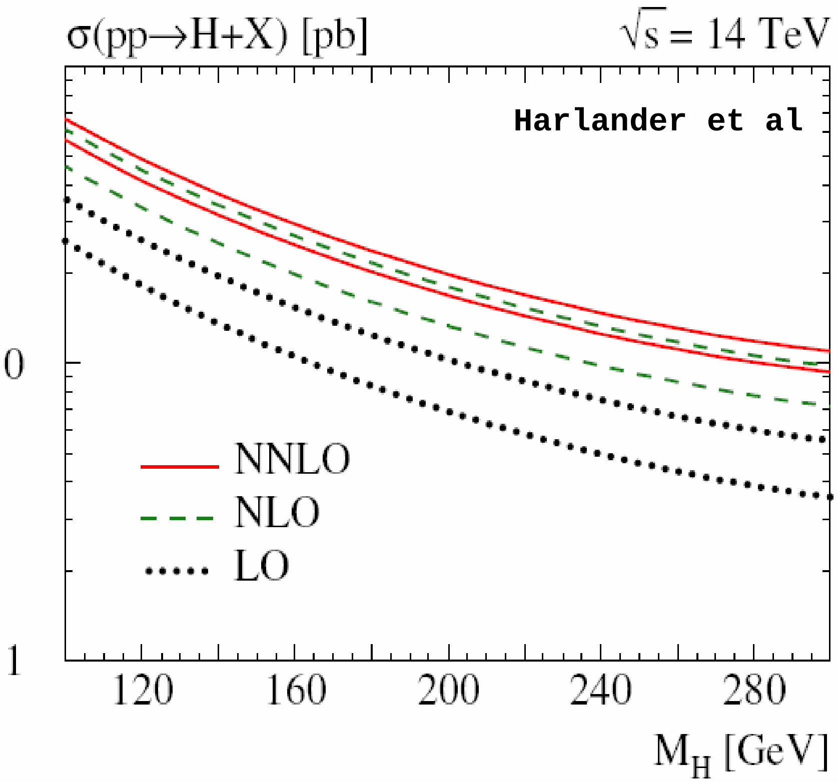


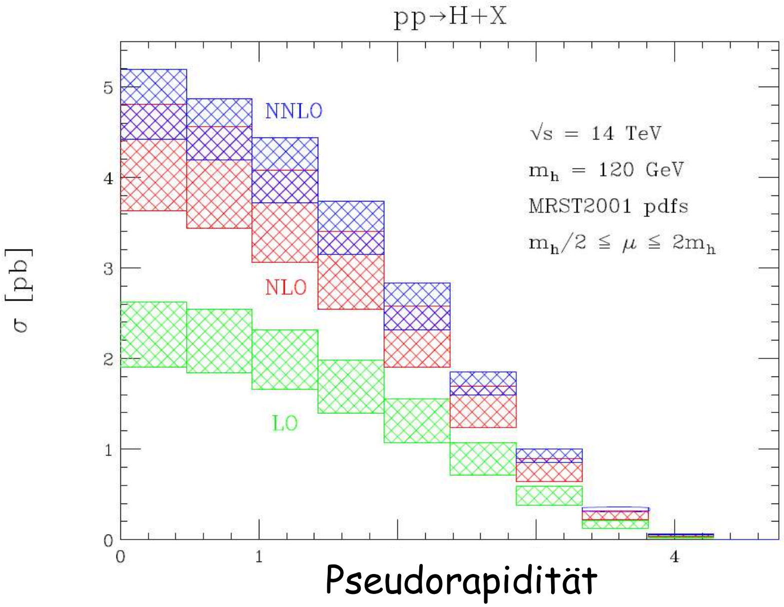
Spira et al





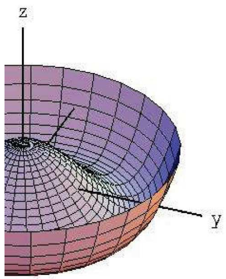
Loop corrections are important!





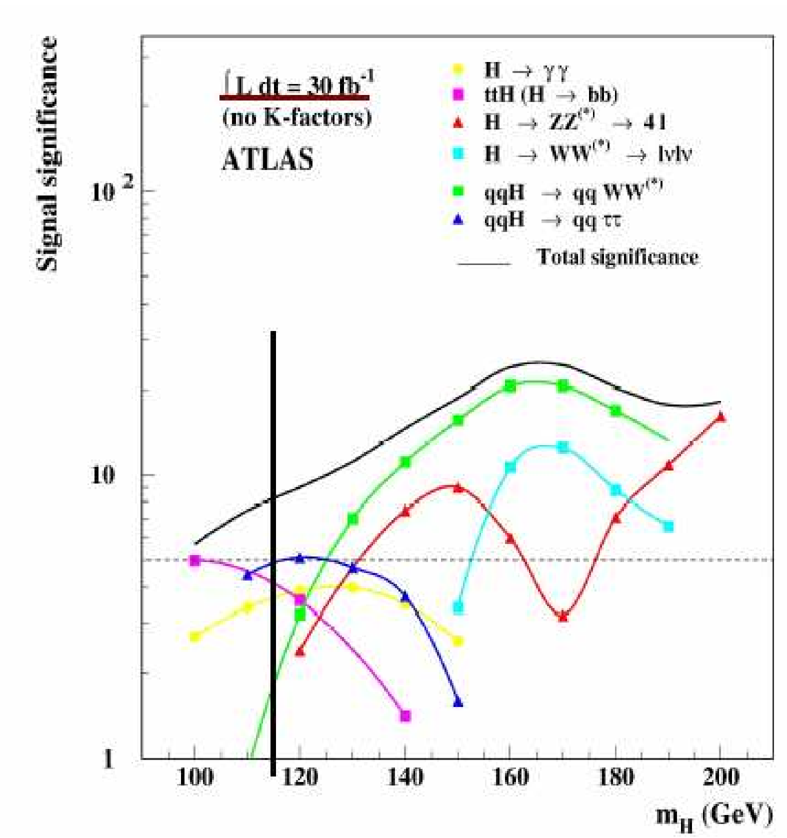
complicated and tedious multi-loop calculation are vital and deserve our acknowledgement!

needed both for LHC and ILC



Higgs discovery at the LHC

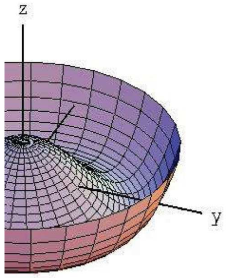
light (m_H<140 GeV) Higgs:
early discovery (10 fb^{-1}) through combination of 3 channels possible (good or bad?)



m_H=115 GeV significance for $10fb^{-1}$:

	S	B	$S/\sqrt{B}$
$H \to \gamma\gamma$	130	4300	2.0
ttH,H→bb	15	45	2.7
qqH,$H \to \tau\tau$	10	10	2.7

combinied: ~4σ



After discovery

peak in mass spectrum is no proof of the Higgs mechanism yet…

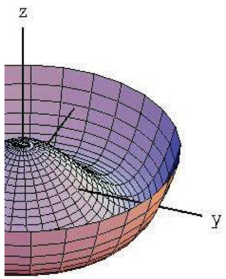
needed measurements:

- masse, total width
- spin, CP = 0^+
- coupling to gauge bosons ~ m_V
- coupling to fermions ~ m_f (Yukawa mechanism)
- self coupling of Higgs bosons (shape of Higgs potential)

Aim:

1. Confirm Higgs mechanism
2. Learn about its realisisation: (1 doublett or more complicated)

→ sensitivity to physics beyond the Standard Model



Measurements at LHC

Mass

<140 GeV: from $H \to \gamma\gamma$
>140 GeV: from $H \to 4l$

$\Delta m/m \sim 10^{-3}$

Total width:

not possible for m<200 GeV
($\Gamma_{Higgs} \ll \Gamma_{Detector}$)

$\Delta\Gamma/\Gamma \sim 20\%$ (250 GeV)
$\Delta\Gamma/\Gamma \sim 5\%$ (400 GeV)

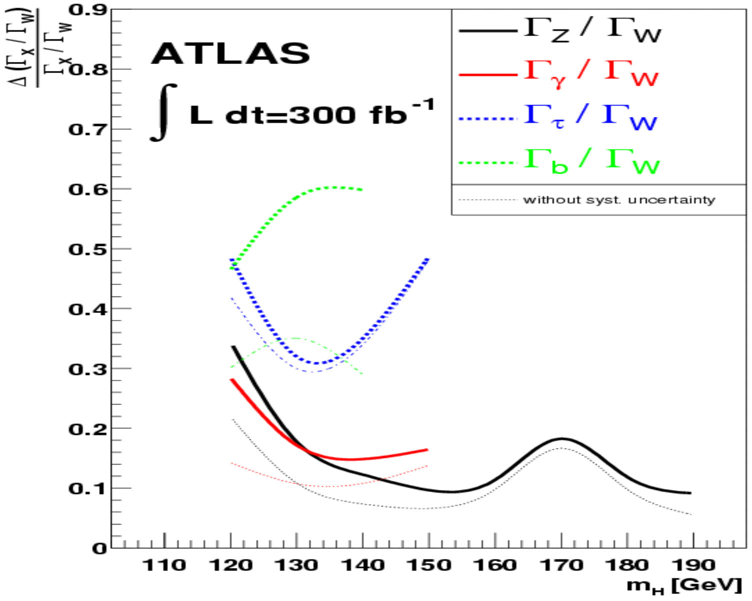
from lineshape in $H \to ZZ \to 4l$

Couplings:

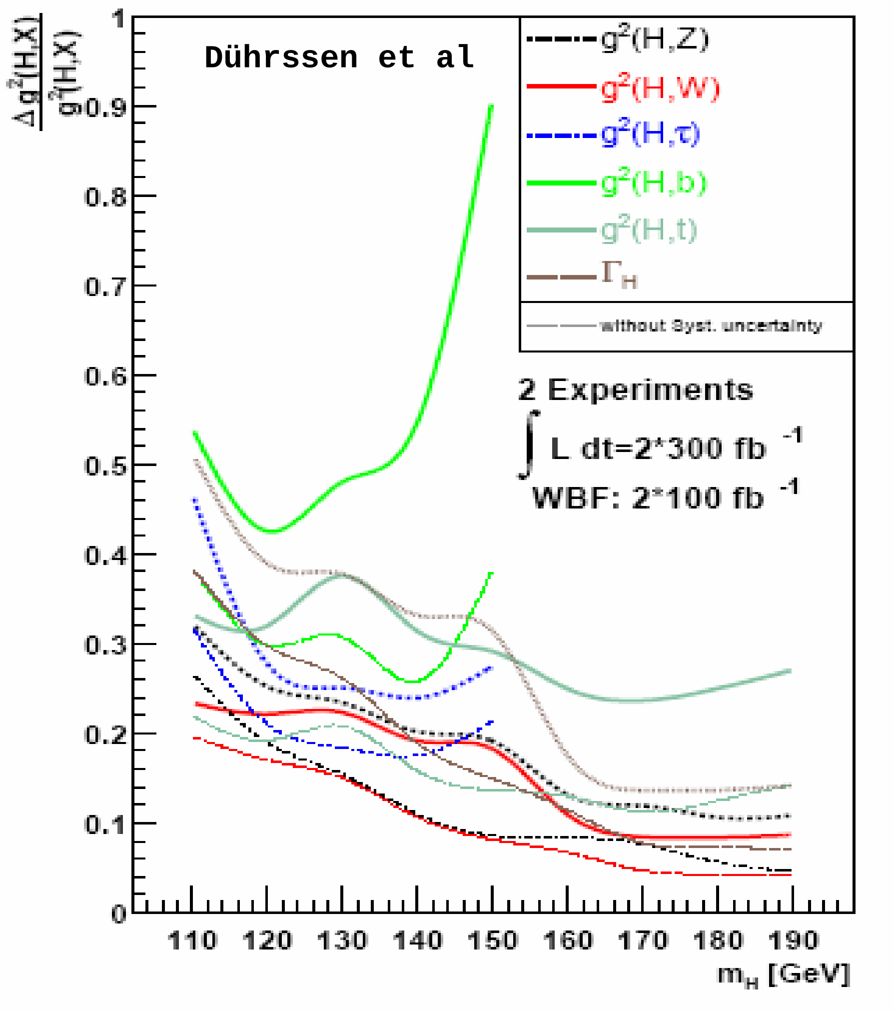
Production rates always contain products of couplings

rations of rates ~
rations of partial widths

global Fit with 13 final states



Measurements at LHC

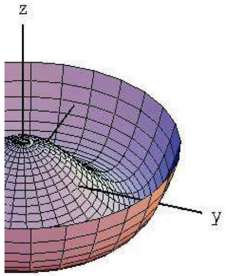


extraction of absolute couplings only with model assumptions:

- $g_V <= g_V^{SM}$

precision on $\Delta g^2/g^2$ ~ 20-50% on Z,W,τ,b,t

large contribution of systematic error (QCD+PDF-uncertainty in production)



So what will be left to do?

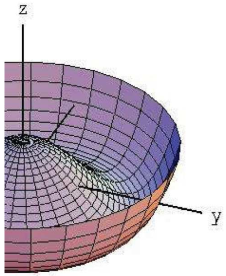
- (likely) measure J^{CP} quantum numbers
- measure the Higgs couplings without model assumptions
- measure Higgs Yukawa couplings with decent precision
- measure the Higgs self coupling

- check consistency of Higgs properties with SM precision observables

in order to

- fully establish the Higgs mechanism
- look for deviations from SM Higgs realisation

needs a precision instrument



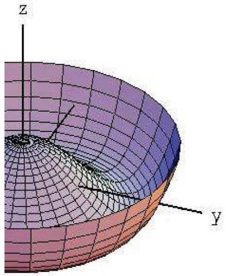
Electron Positron Collisions

Electron positron collisions at high energy provide a powerful tool to explore TeV-scale physics complementary to the LHC

Due to their point-like structure and absence of strong interactions there are clear advantages of e^+e^- collisions:

- known and tunable centre-of-mass energy
- clean, fully reconstructable events
- polarized beams
- moderate backgrounds
  → no trigger

→broad consensus for a Linear Collider with up to at least ~500 GeV



The International Linear Collider

Huge world-wide effort to be ready for construction in 2009/10
(Global Design Effort GDE)
Result of an intense R&D process since 1992

Parameters (ICFA parameter document/ILC baseline)

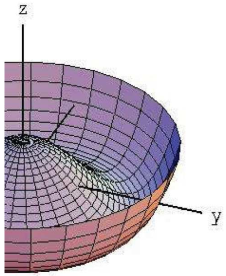
The baseline:
e^+e^- LC operating from M_Z to 500 GeV, tunable energy
e^- /e^+ polarization
at least 500 fb^{-1} in the first 4 years

Upgrade: to ~ 1 TeV 500 fb^{-1} /year

Options :
- GigaZ (high luminosity running at M_Z)
- $\gamma\gamma$, $e\gamma$, e^-e^- collisions

NB: currently
being reviewed...

Choice of options depends on LHC+ILC results



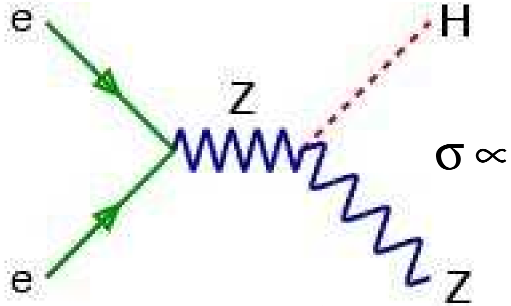
The ILC physics case

0. Top quark at threshold
1. 'Light' Higgs (consistent with precision EW)
   ➪ verify the Higgs mechanism is at work in all elements
2. 'Heavy' Higgs (inconsistent with precision EW)
   ➪ verify the Higgs mechanism is at work in all elements
   ➪ find out why prec. EW data are inconsistent
3. 1./2. + new states (SUSY, XD, little H, Z', …)
   ➪ precise spectroscopy of the new states
   ➪ precision measurements of couplings of SM&new states properties of new particles above kinematic limit
4. No Higgs, no new states (inconsistent with precision EW)
   ➪ find out why precision EW data are inconsistent
   ➪ look for threshold effects of strong/delayed EWSB

Early LHC data likely to guide the direction → choice of ILC options and upgrade to 1 TeV depends on LHC+ILC(500) results

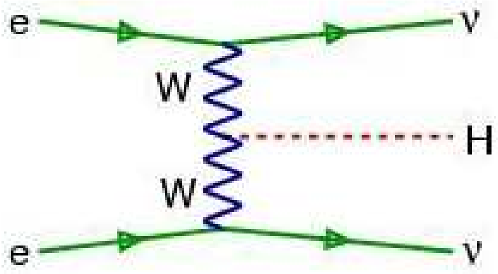
LHC + ILC data analysed together → synergy!

Higgs production at the ILC



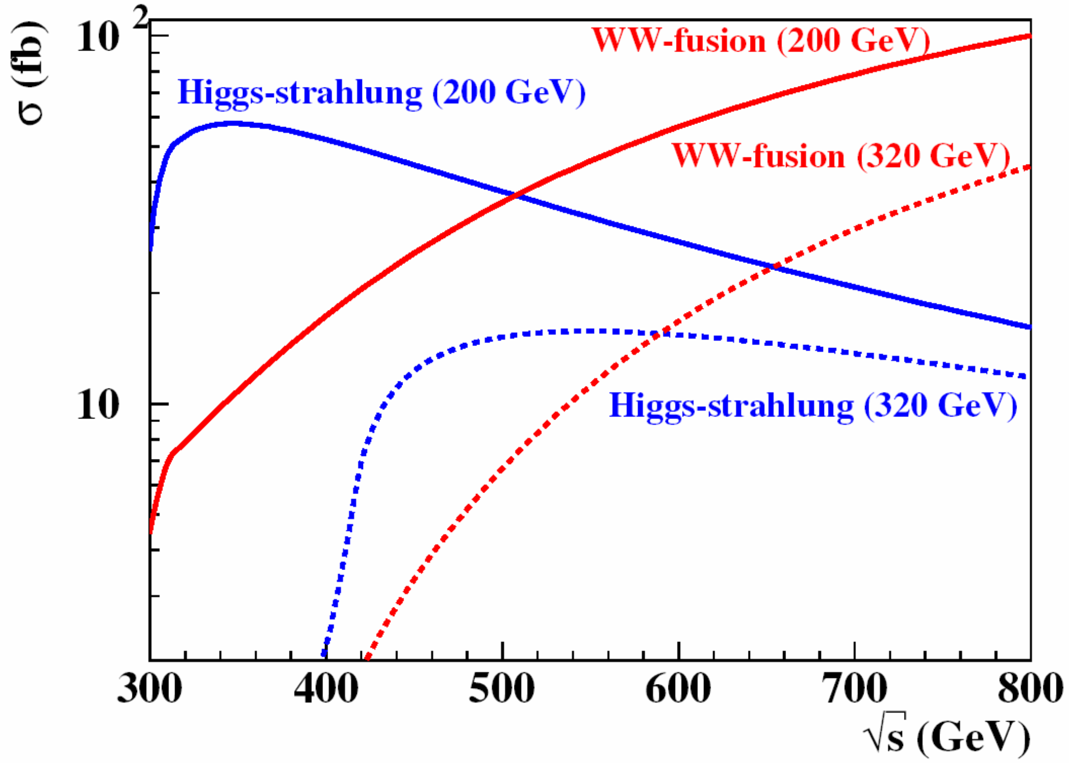
$\sigma \propto\sim 1/s$

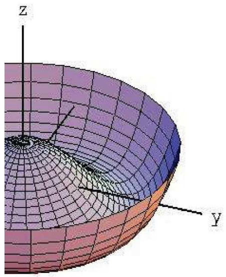
Higgsstrahlung



$\sigma \propto\sim \ln s$

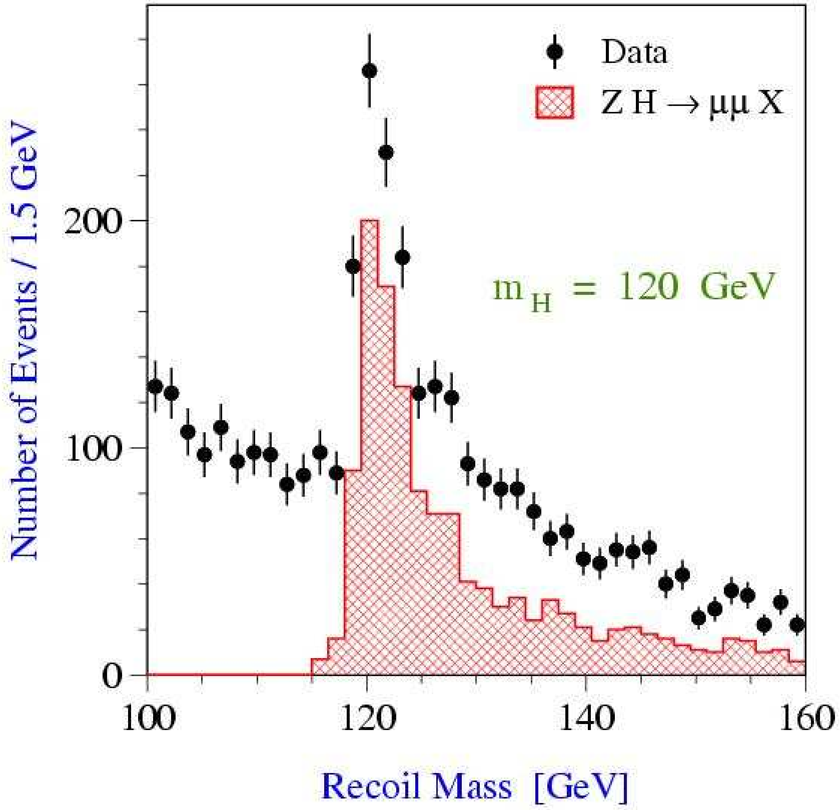
WW-Fusion

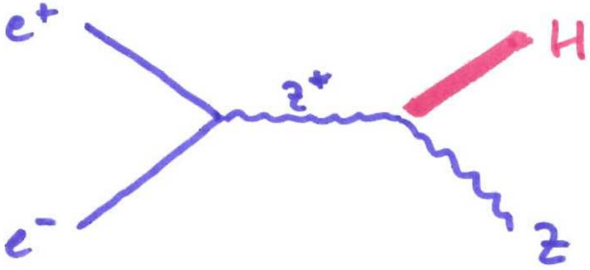




Seeing it without looking at it

anchor of Higgs physics at ILC:
decay-mode independent observation

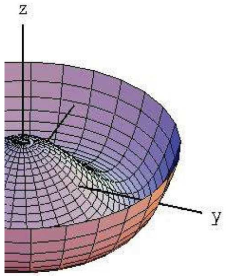




$m_H^2 = (p_{\ell\ell} - p_{\text{initial}})^2$

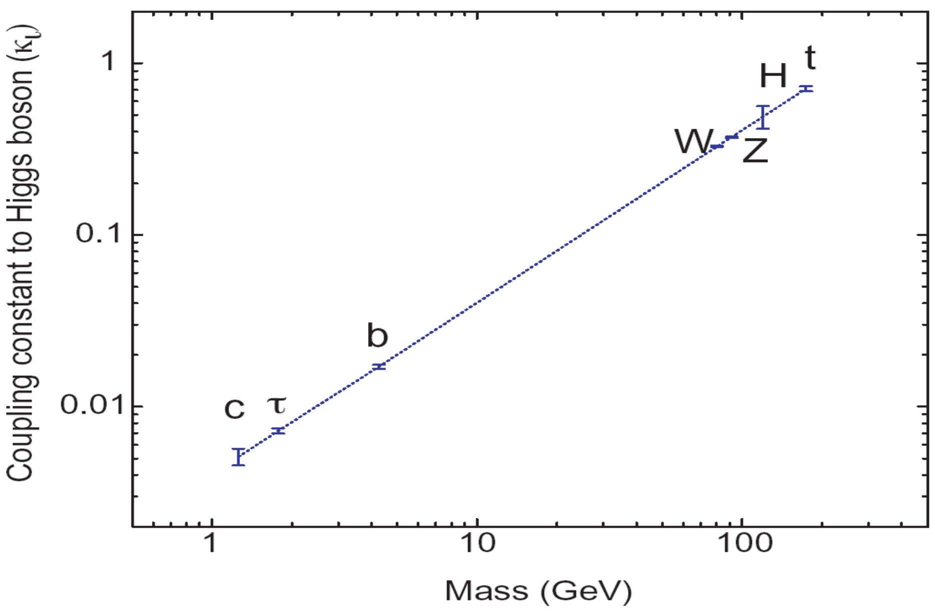
recoil mass

Δσ/σ ~ 2%
Δm/m ~ 50 MeV
HZ coupling ~ 1%



Higgs branching ratios

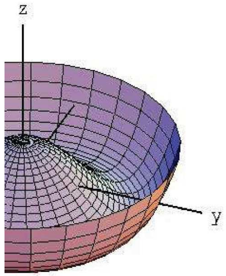
best option to test Yukawa mechanism
$\Gamma(H \rightarrow ff) \sim m_f$?



precision: ~%

At the ILC we can measure absolute branching ratios because decay-independent measurement of g_{HZ}:

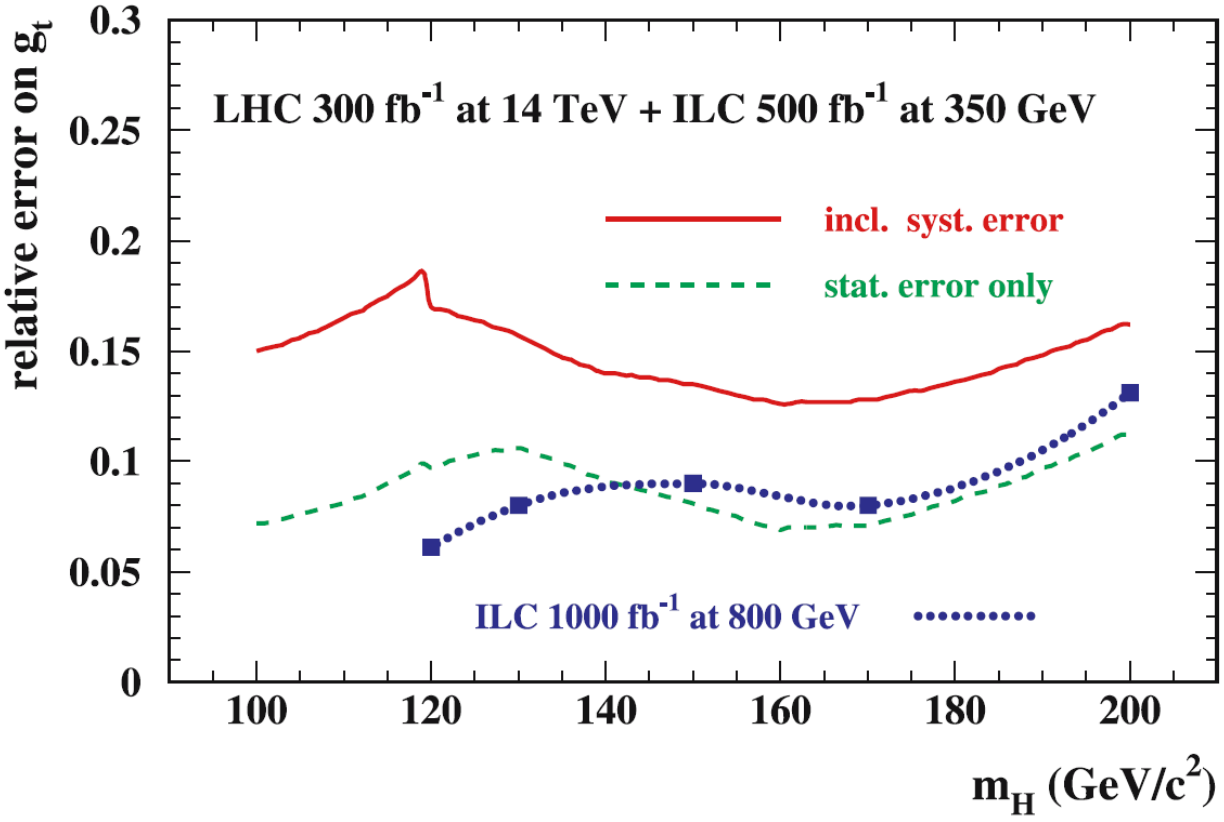
$$BR(H \rightarrow X) = \frac{[\sigma(HZ) \cdot BR(H \rightarrow X)]^{meas}}{\sigma(HZ)^{meas}}$$

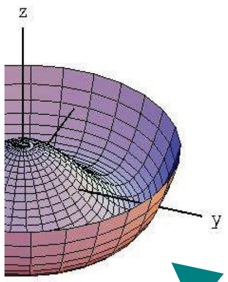


Top Yukawa coupling: LHC+ILC synergy

LHC: measures
$\sigma_{tth} \times BR(H \rightarrow bb)$
$\sigma_{tth} \times BR(H \rightarrow WW)$
$\rightarrow g_t^2 \times BR(H \rightarrow xx)$

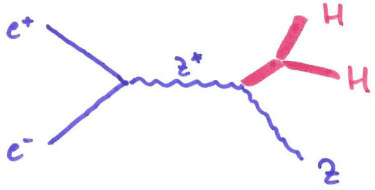
ILC: measures BRs
$BR(H \rightarrow bb)$
$BR(H \rightarrow WW)$





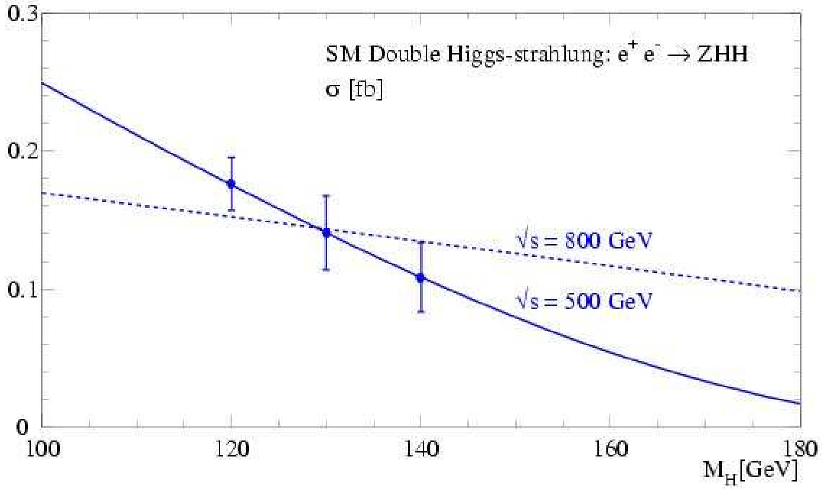
Higgs self coupling

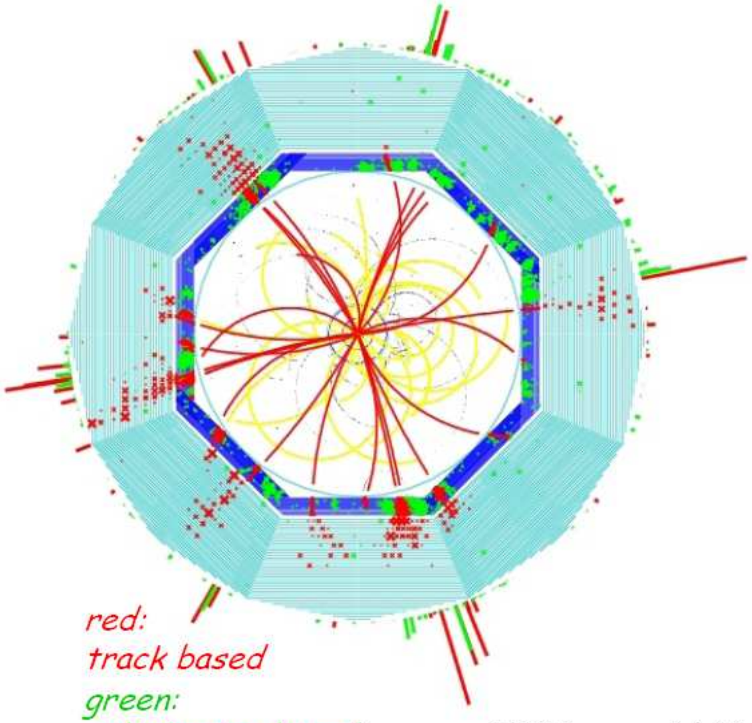
closely linked to shape to Higgs potential
→ most important test of spontaneous symmetry breaking



measurement at LHC seems imposs

ILC: double Higgs-Strahlung:

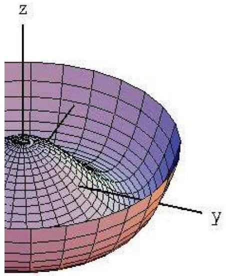




red:
track based
green:
calorimeter based

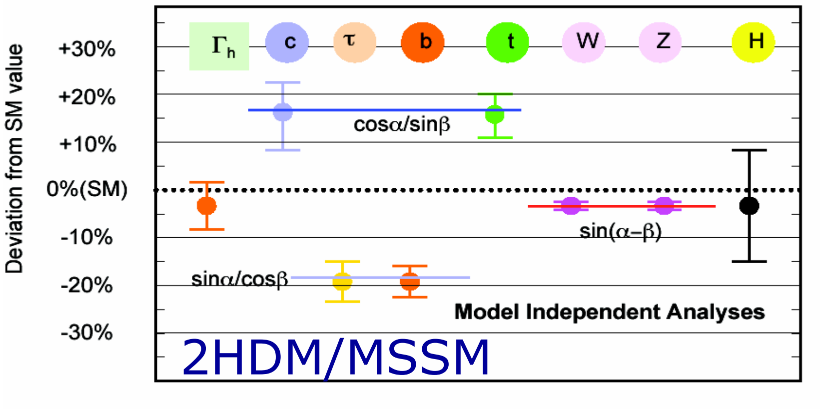
ZHH → qqbbbb

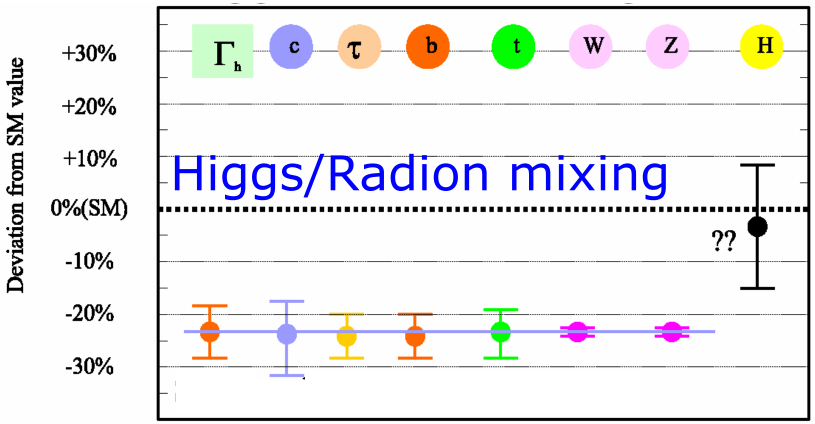
$\Delta\lambda/\lambda$ = 20% @ 500 GeV
12% @ 1 TeV (?)



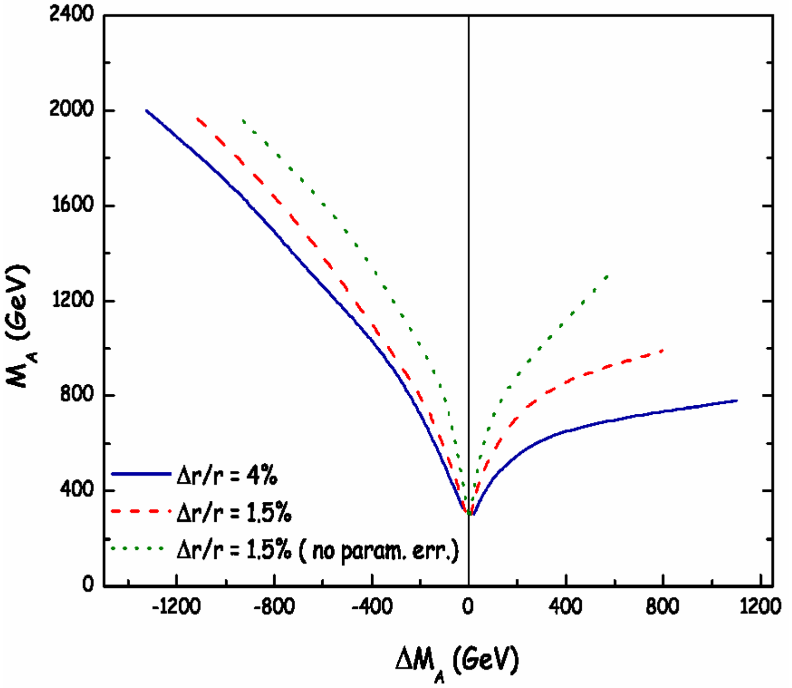
Why is precision so important?

distinguish models



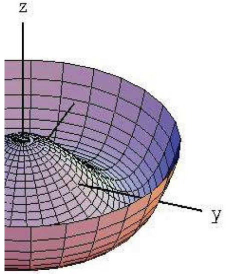


indirect mass determination of heavy Higgses, if there (MSSM):



Δm_A = 30% for m_A = 800 GeV

also in parameter regions where LHC is blind

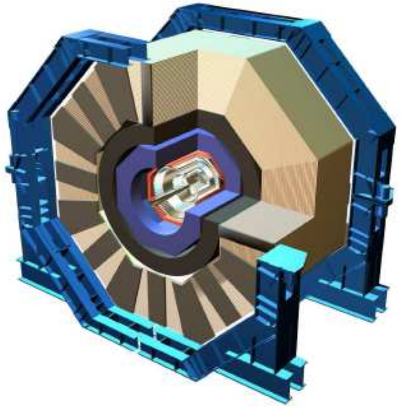


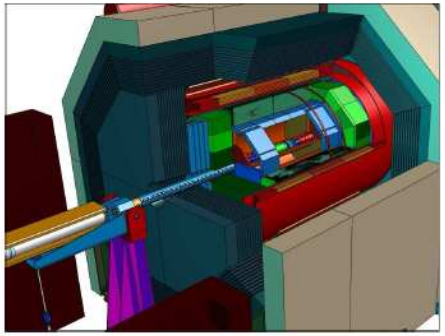
How to achieve this precision? – Detectors!

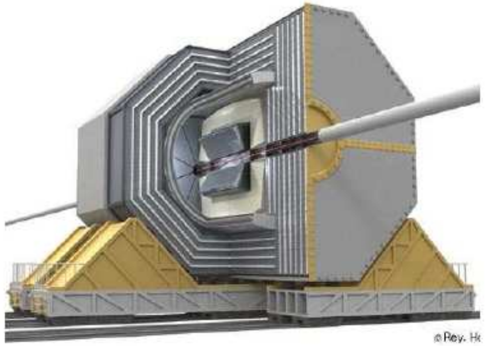
Choices:
Size: large – medium – small (B-field)
Calorimetry: Particle Flow or E-resolution?
Tracking: Silicon or Gaseous?
Muons: instrumented iron or double solenoid?

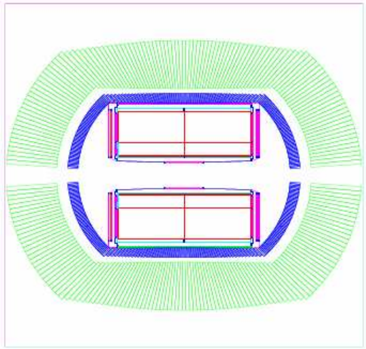
Common:
vertex detector
forward instrumentation

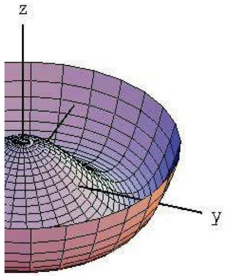
Optimization:
performance vs. cost


SiD


LDC


GLD

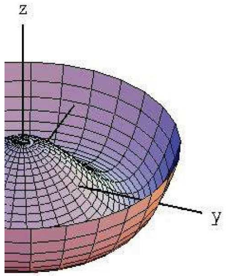

4th



The Ideal ILC Detector

would measure something like this:

```
================================================================================
   3 !e+!          21      -11     1     0.000     0.000   400.000   400.000     0.001
   4 !e-!          21       11     2     0.000     0.000  -400.000   400.000     0.001
   5 !e+!          21      -11     3     0.000     0.000   400.000   400.000     0.000
   6 !e-!          21       11     4     0.000     0.000  -400.000   400.000     0.000
   7 !Z0!          21       23     0     0.000     0.000     0.000   800.000   800.000
   8 !t!           21        6     7    41.155    57.303  -352.640   400.439   176.123
   9 !tbar!        21       -6     7   -41.155   -57.303   352.640   399.561   174.118
  10 !W+!          21       24     8    68.018    62.988  -232.415   262.948    80.814
  11 !b!           21        5     8   -36.648   -14.839    -8.097    40.643     4.800
  12 !W-!          21      -24     9   -34.659   -87.829    98.869   156.649    76.477
  13 !bbar!        21       -5     9    38.081    22.927   -15.127    47.198     4.800
  14 !dbar!        21       -1    10    48.580    39.784   -56.545    84.500     0.330
  15 !u!           21        2    10    19.128    22.953  -175.063   177.595     0.330
  16 !d!           21        1    12   -48.424   -60.075    33.387    84.076     0.330
  17 !ubar!        21       -2    12    14.405   -26.560    64.202    70.957     0.330
```

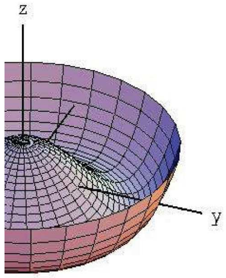


The Ideal ILC Detector

the best we could hope for:

```
...
125 pi+           1     211   59    1.690   -0.865   -1.257    2.281    0.140
126 pi-           1    -211   59    1.955   -0.869   -1.646    2.703    0.140
127 (eta)        11     221   59    2.814   -1.261   -2.331    3.904    0.547
128 pi-           1    -211   60    0.065    0.005    0.044    0.160    0.140
129 pi+           1     211   60    0.475   -0.601   -1.026    1.288    0.140
130 pi+           1     211   62    1.478   -0.729   -1.135    2.006    0.140
131 (pi0)        11     111   62    8.427   -5.137   -8.188   12.824    0.135
132 nu_taubar     1     -16   63    8.732   -5.586   -7.281   12.667    0.000
133 (tau-)       11      15   63   16.252   -7.858  -13.819   22.803    1.777
134 (D*0)        11     423   63   35.949  -20.857  -31.248   52.036    2.007
135 pi-           1    -211   65   -0.606   -2.085   -2.852    3.588    0.140
136 pi+           1     211   65   -2.509   -8.867  -10.402   13.898    0.140
137 pi+           1     211   66   -0.514   -1.198   -1.532    2.017    0.140
138 (pi0)        11     111   66   -1.021   -6.020   -6.541    8.949    0.135
139 pi+           1     211   68   -0.233   -1.549   -1.620    2.258    0.140
140 (pi0)        11     111   68   -3.732  -13.740  -13.880   19.884    0.135
141 gamma         1      22   71   -2.608  -10.515  -10.281   14.935    0.000
142 gamma         1      22   71   -1.547   -6.002   -5.765    8.465    0.000
...
```

and then use our knowledge of physics to reconstruct
quarks, gluons, charged leptons, neutrinos(!) as good as possible



The Ideal ILC Detector

To do so, the detector has to provide

- precision tracking for charged particles
- highly granular calorimetry (separate charged from neutral, measure neutral)
- precision vertex detector (identify heavy flavours b,c,τ)
- capability to identify muons
- $4\pi-\varepsilon$ angular coverage
- precise diagnostics of initial state (luminosity, energy, polarisation)
- cope with backgrounds

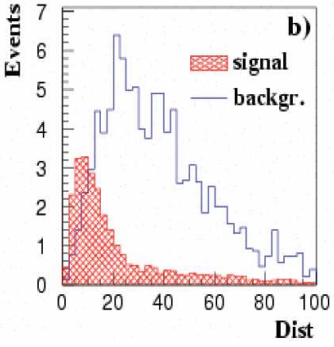
Why does it matter?

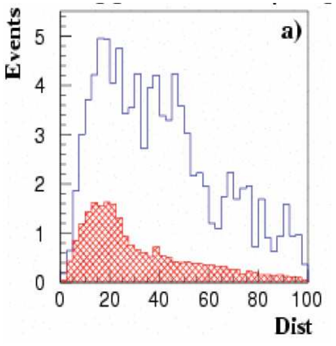
Calorimetry:

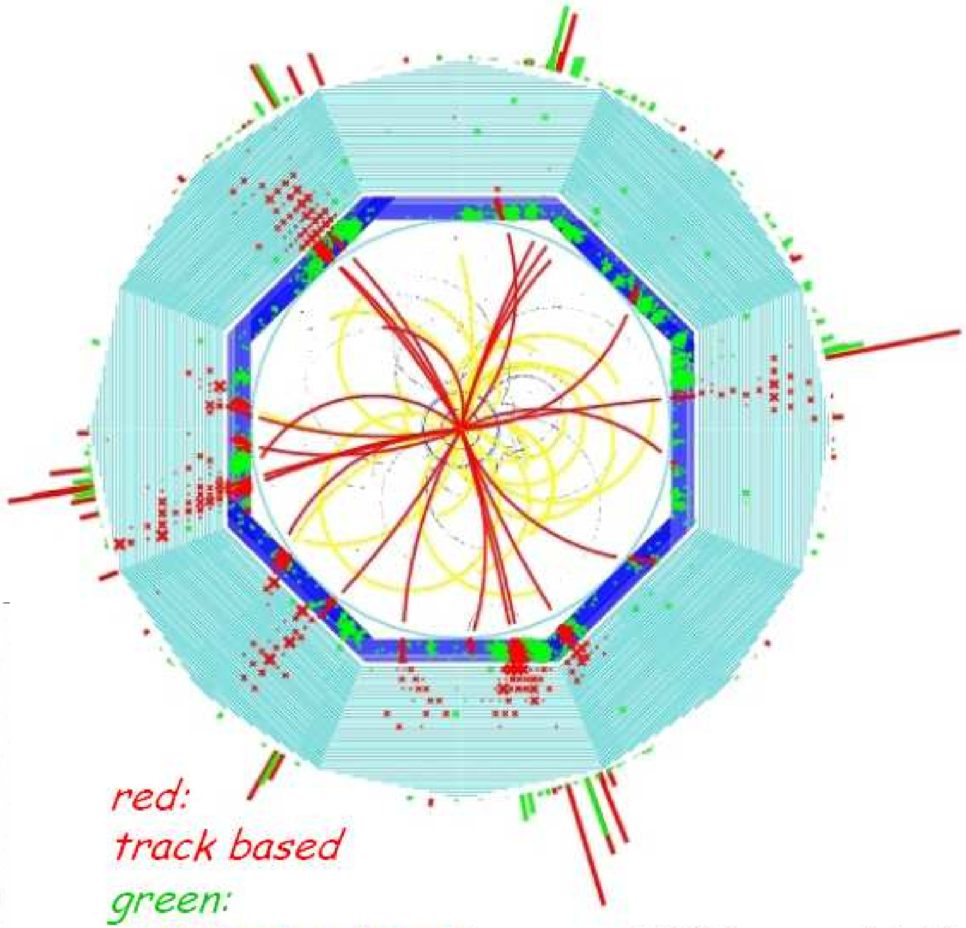
need to measure sub-fb
cross sections
in hadronic final states!

not a question of
better or worse
but a question of

do or don’t







red:
track based
green:
calorimeter based

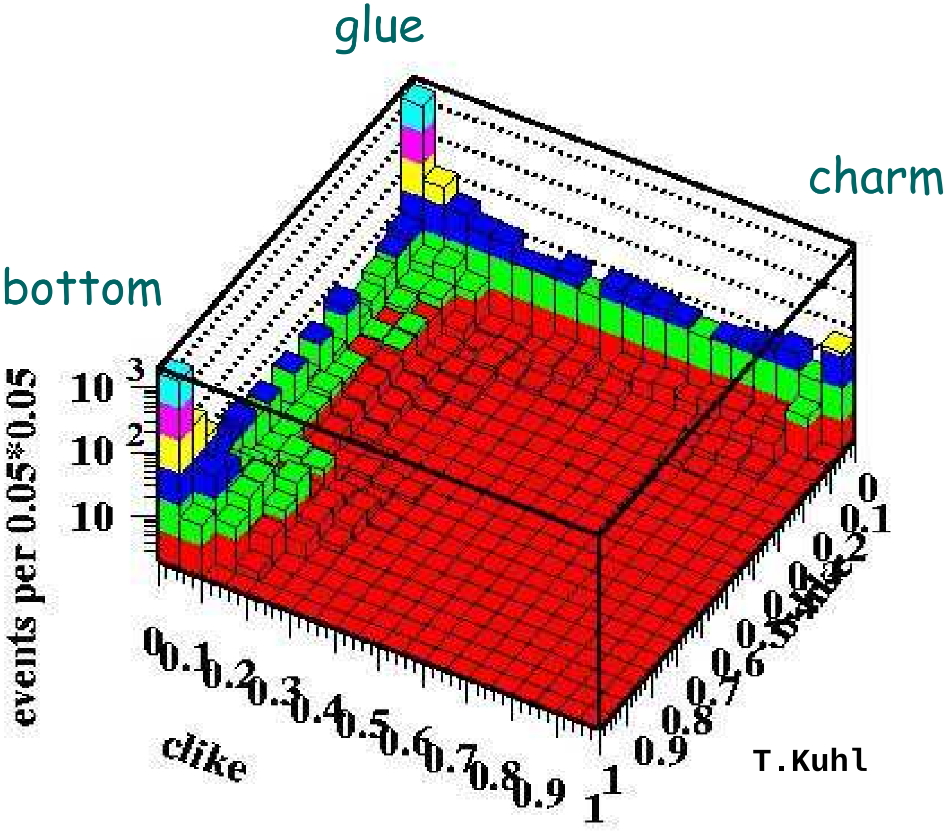
ZHH → qqbbbb

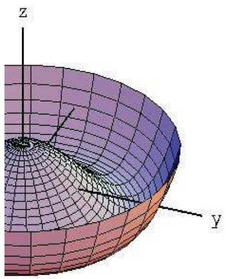
Why does it matter?

Flavour ID:

ILC conditions allow for unprecedented flavour tagging –

only if we manage to build an unprecedented vertex detector



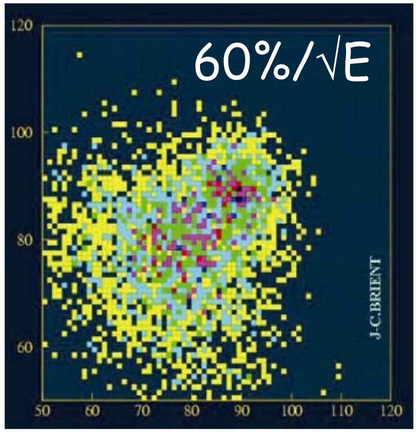


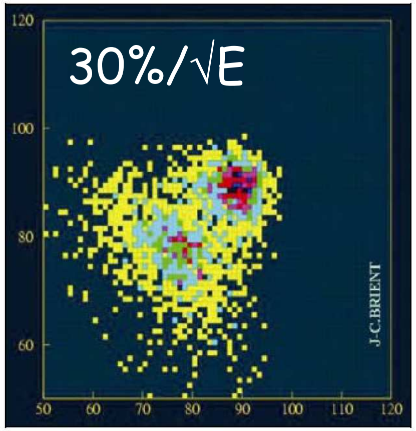
Why does it matter?

High resolution efficient detector increases the effective luminosity

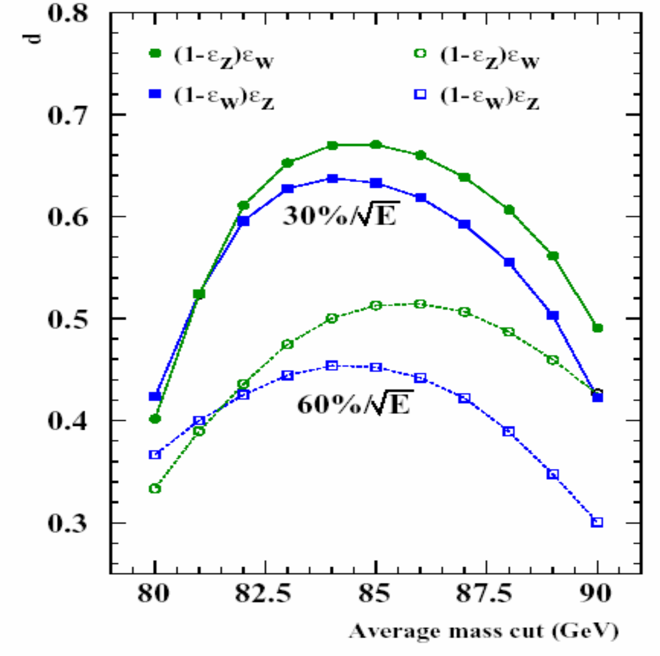
σ(stat) = sqrt($\varepsilon_S S+\varepsilon_B B$)/$\varepsilon_S S$ ~ 1/sqrt(L)
σ(syst) = sqrt($\Delta S^2+\Delta B^2$)/S ~ B/S indep. of L

Better resolution, efficiency, and acceptance mean
- need less luminosity for the same significance
- lowering systematic boundary

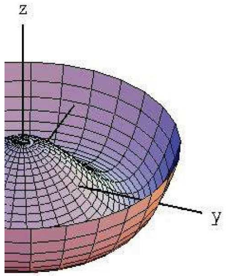




separation of hadronic W and Z:



going from 60% to 30% almost doubles effective luminosity



Detector R&D

Having detector concepts on paper does not necessarily means they can be built

Have seen a lot of 'small-scale' R&D with limited funding in the past
Good progress towards proof-of-principle of technologies

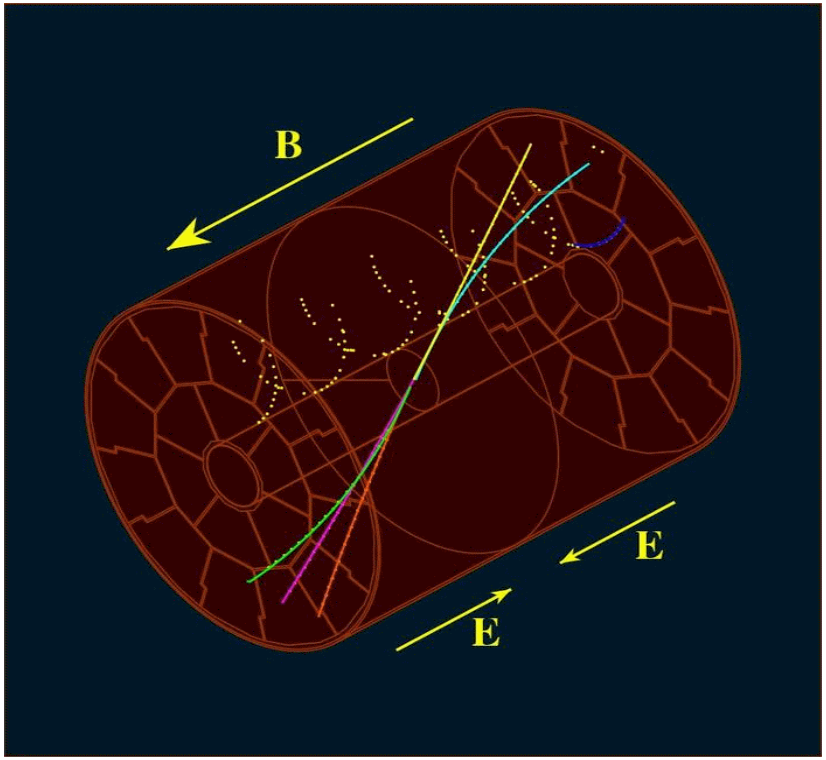
With the tight GDE schedule, we need to
- move towards R&D more focused towards subsystems in concepts
- move from small-scale prototypes to larger system tests
- implement necessary infrastructure for these tests

For many sub-systems international R&D collaborations are in place. e.g.

CALICE – R&D towards a particle flow calorimeter
LC-TPC - R&D towards a high-resolution TPC
SiLC - R&D towards new Silicon detectors and Readout
LCFI, CMOS, DEPFET – R&D towards an ILC vertex detector
Forward Calorimetry

Example: Tracking

TPC – elegant principle for charged particle tracking with ~ no material

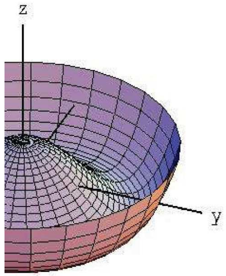


Challenges:

Minimize material in endplate

Maximize spatial resolution

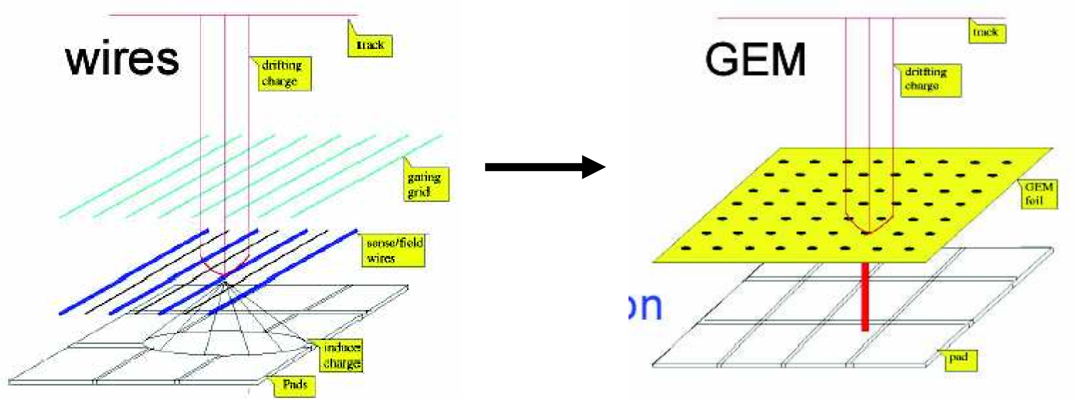
Maximize robustness
+ redundancy



TPC R&D

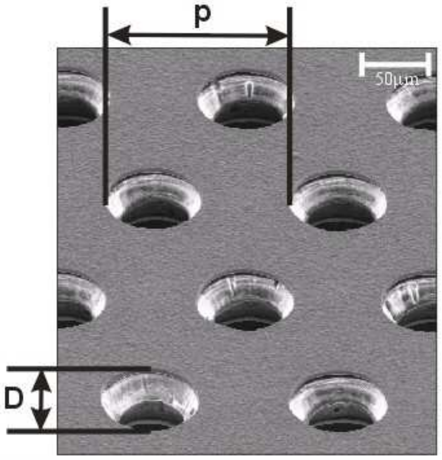
Use Micro Pattern Gas Detectors (GEMs, MicroMegas) for gas amplification

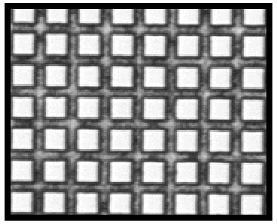
- inherent 2D structure
- natural ion-feedback suppression
- low material budget in end-plate

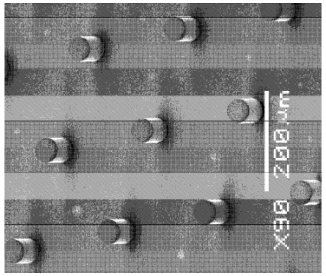


R&D issues:

-stable operation on large scale
- optimize resolution/pad geometry
- pad or pixel readout?
- operation in magnetic field
- field cage design



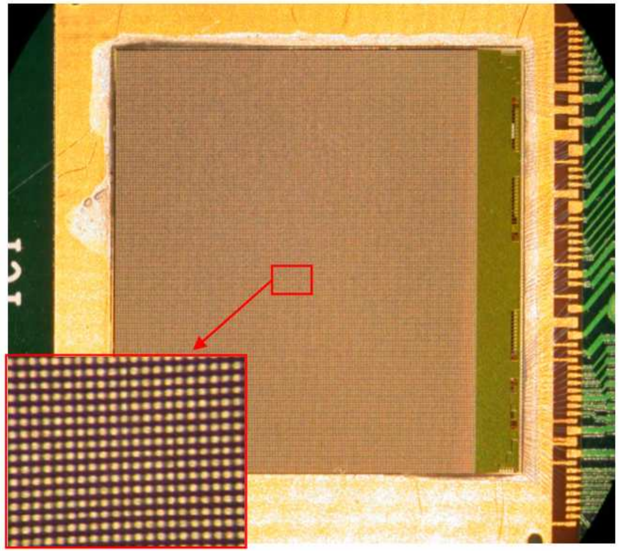




TPC R&D

Freiburg/Bonn-Prototype

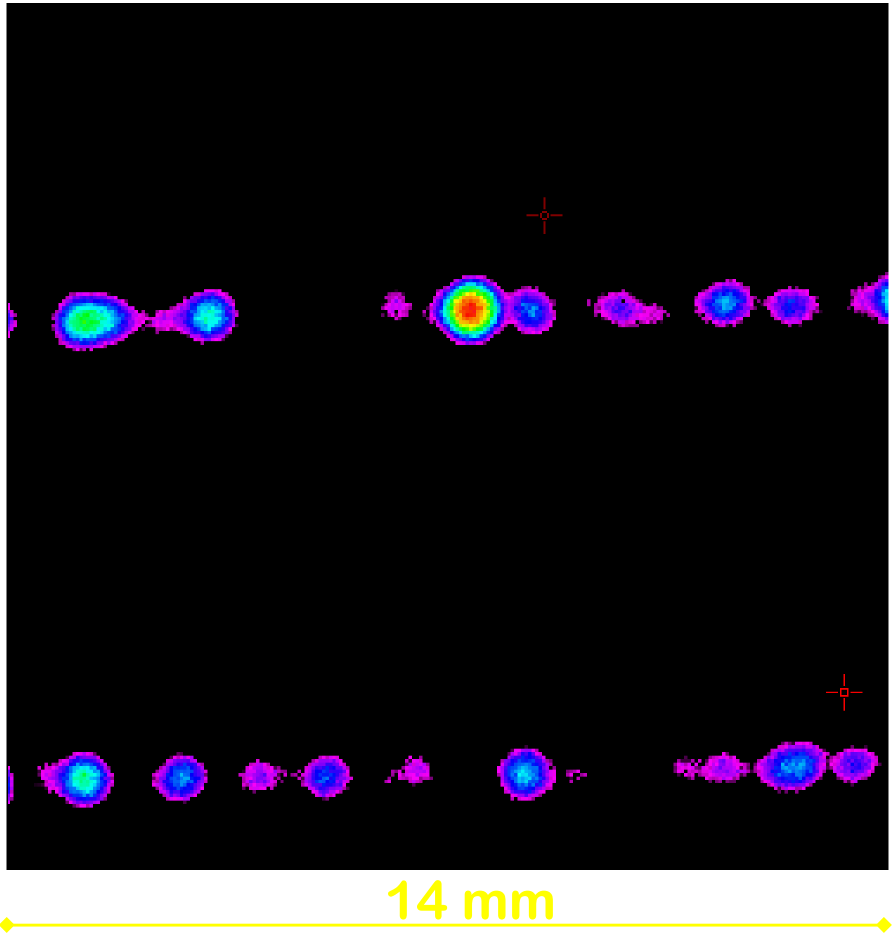
Timepix-Chip (CERN):

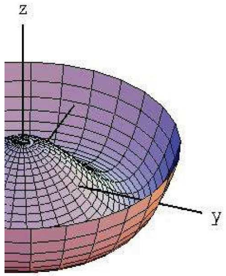


55 μm pixel pitch

Achieved point resolution
of 20 μm (for 0 drift length)

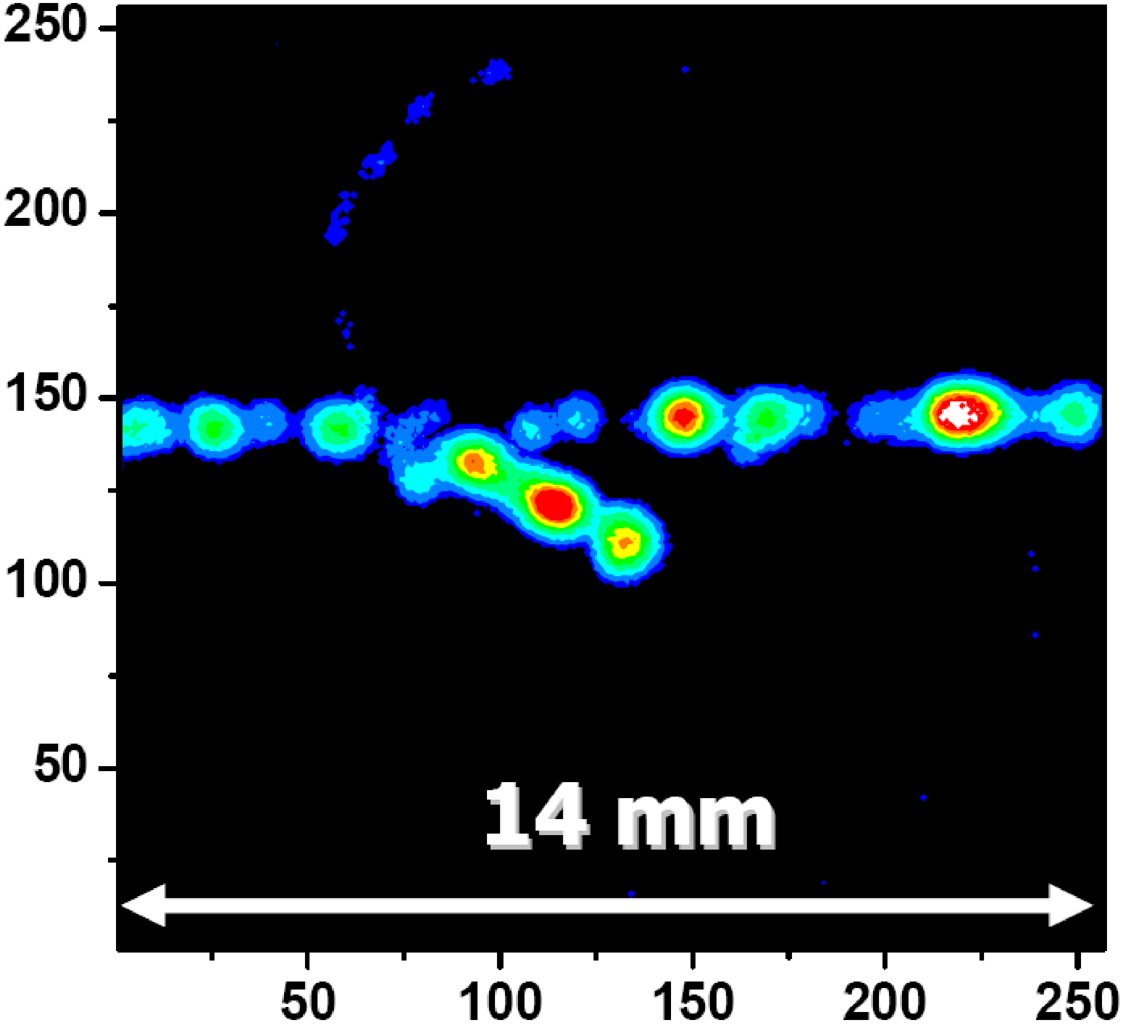
first tracks at DESY test beam

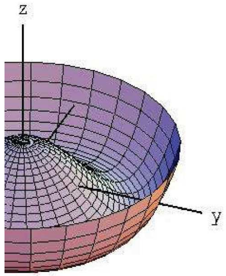




TPC R&D

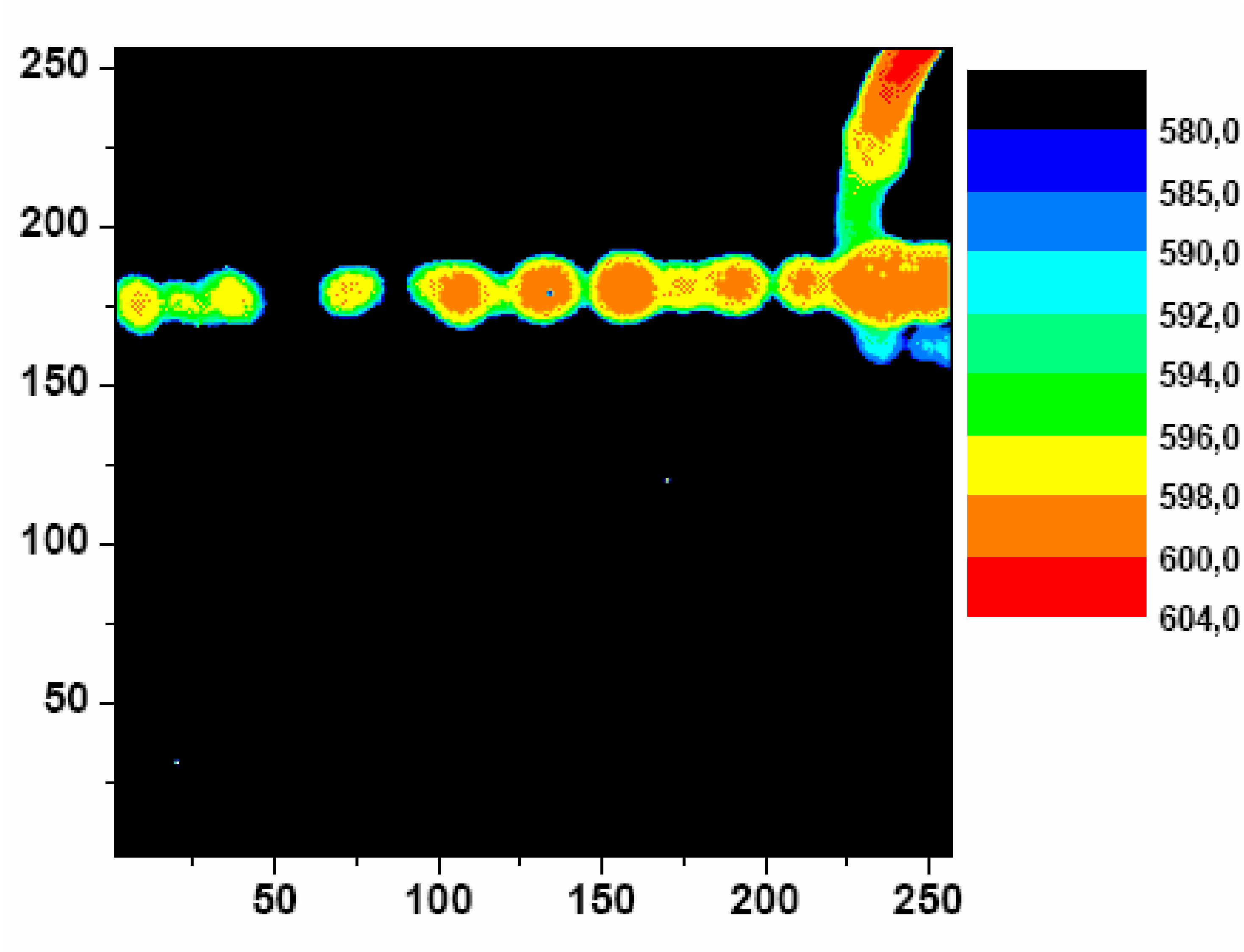
5GeV e^- tracks
with δ-electron(s)





TPC R&D

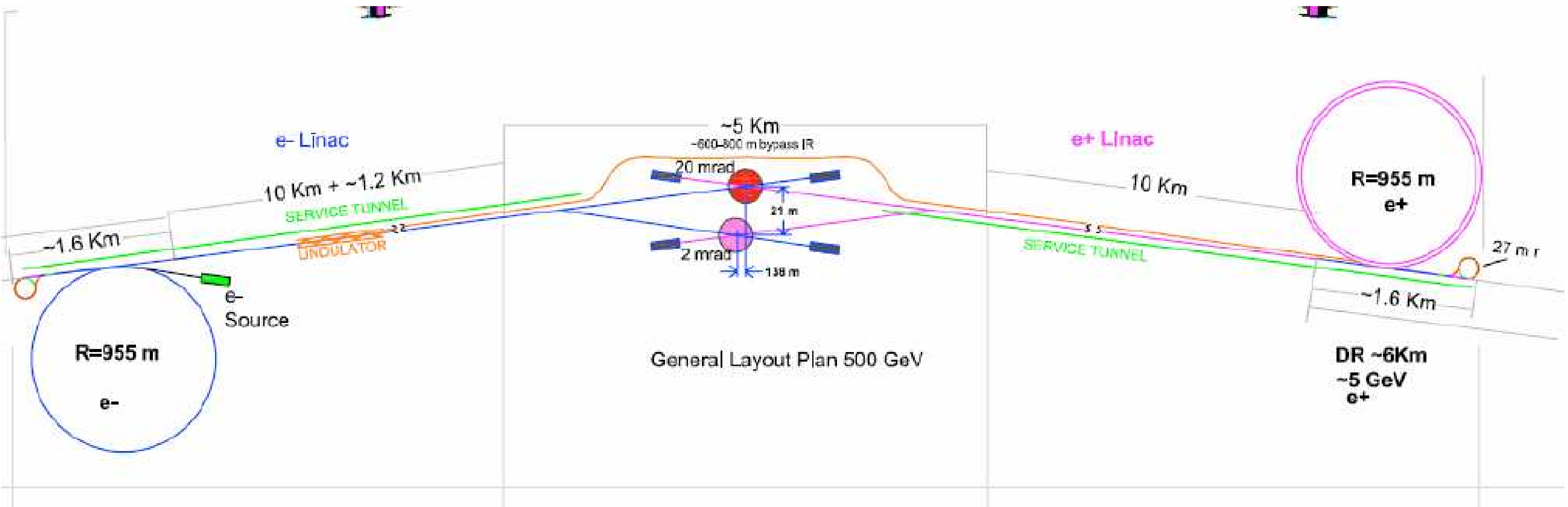
TIME mode



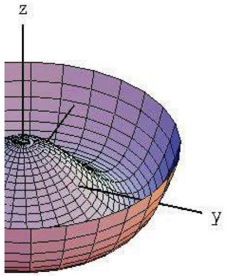
The ILC Project - Planning

Global Design Effort started in 2004 after decision for superconducting technology (B.Barish GDE director)

Fixed a “base-line design” early 2006

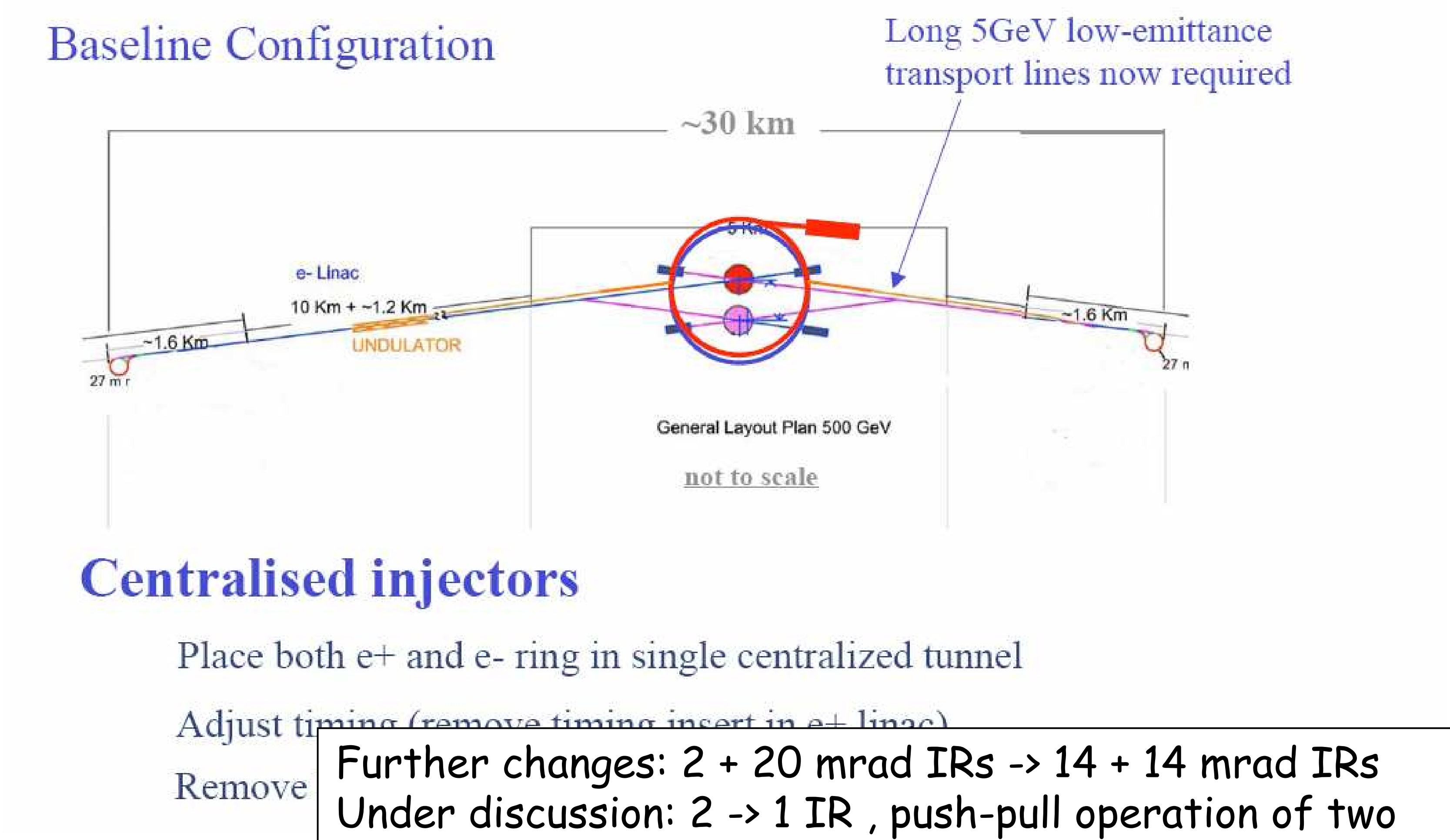


Major changes w.r.t. TESLA
- circular damping rings
- two tunnels
- crossing angle



The ILC project

since then: cost optimisation!



Baseline Configuration

Long 5GeV low-emittance transport lines now required

General Layout Plan 500 GeV

not to scale

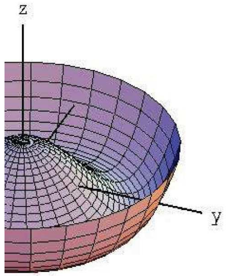
Centralised injectors

Place both e+ and e- ring in single centralized tunnel

Adjust timing (remove timing insert in e+ linac)

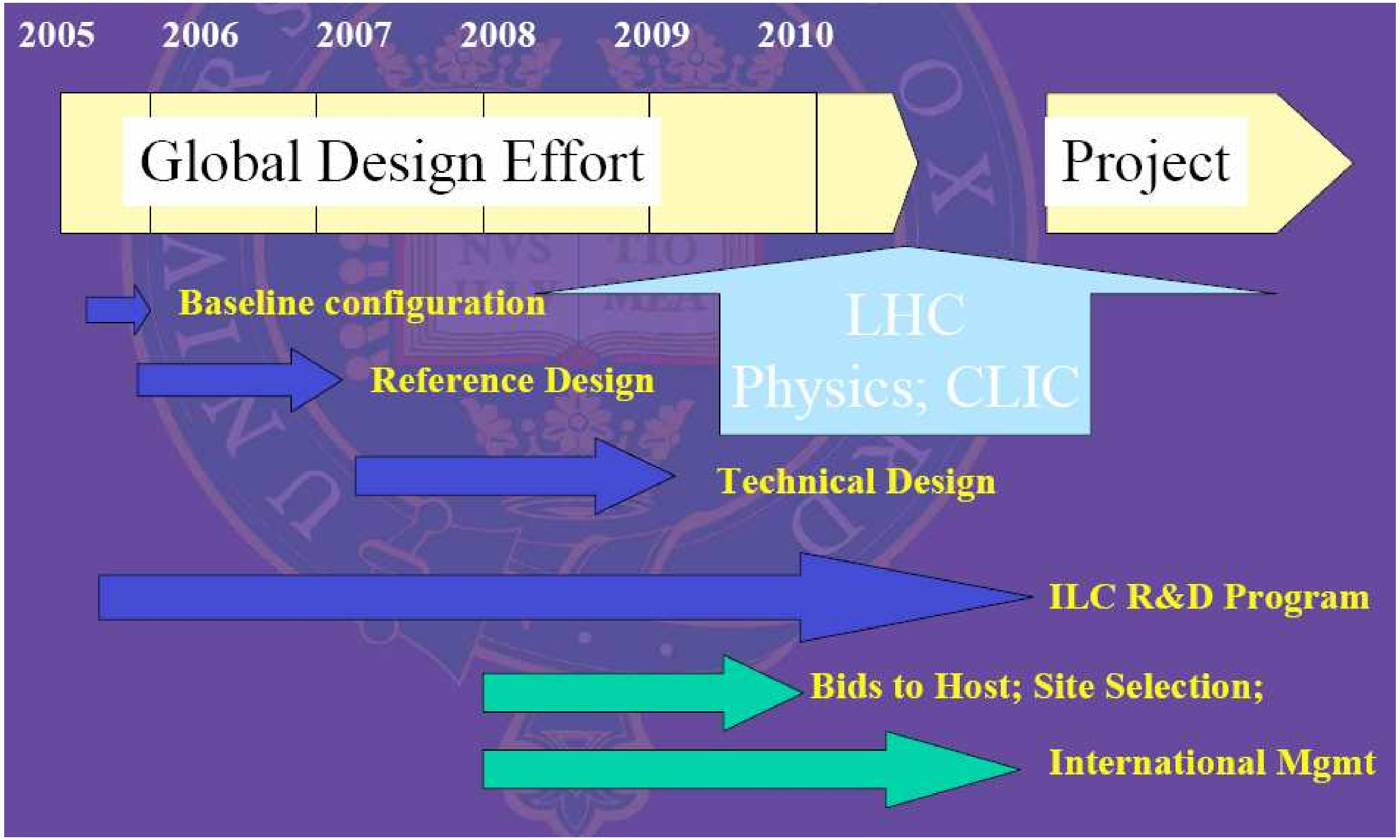
Remove

Further changes: 2 + 20 mrad IRs -> 14 + 14 mrad IRs
Under discussion: 2 -> 1 IR , push-pull operation of two detectors



ILC project – next steps

Next major step: expect costed “Reference Design Report” (RDR) due in February 07 (Beijing workshop)



2005 2006 2007 2008 2009 2010

Global Design Effort

Project

Baseline configuration

Reference Design

LHC
Physics; CLIC

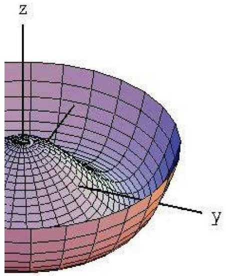
Technical Design

ILC R&D Program

Bids to Host; Site Selection;

International Mgmt

from B.Foster



Summary + Conclusions

Concept of Higgs mechanisms passes all experimental tests since 42 years – without being experimentally confirmed!

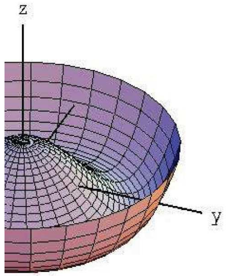
Best completion of SM – but not guaranteed

With Tevatron and (in particular) LHC, we do have the right tools to know very soon if there is (at least) one Higgs-Boson

An Electron Positron Collider like the ILC is indispensable to understand if and how the Higgs mechanism is at work

Detector R&D for ILC detectors is technically challenging and necessary now (and attractive now that LHC detectors are ~completed)

ILC-GDE is on a good way – will know cost soon

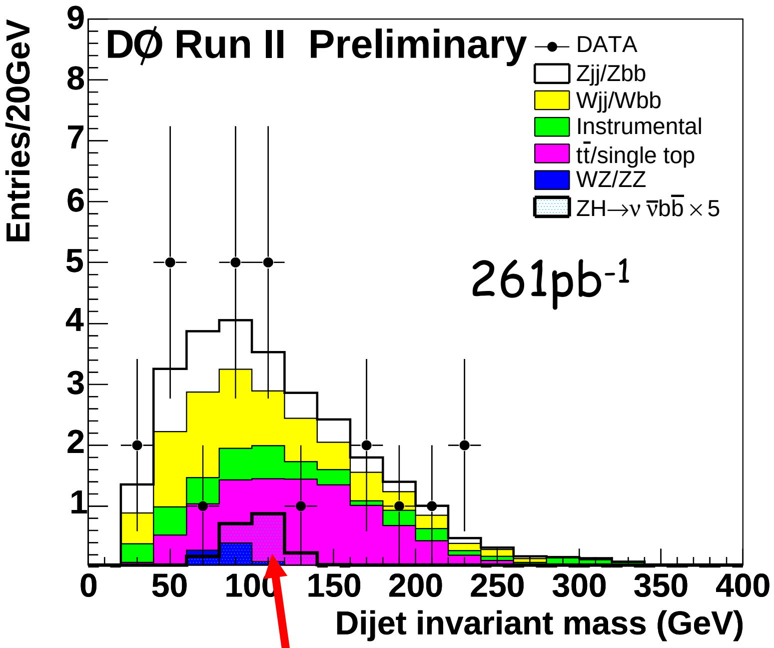


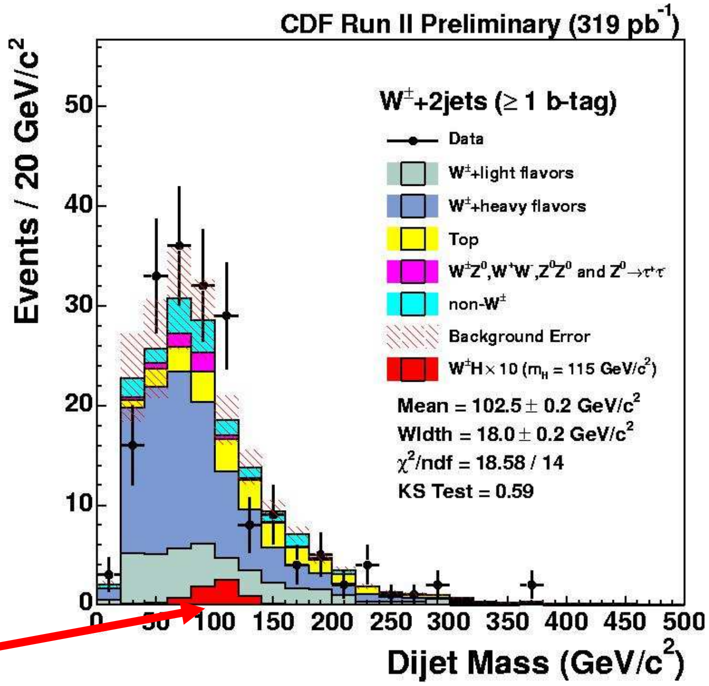
Higgs-Suche am Tevatron

Beispiele:

ZH→ννbb

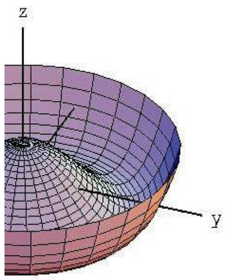
WH→lνbb





SM-Higgs(115) * 10

Bei höherer integrierter Luminosität wird auch besseres S/B benötigt
-härtere Schnitte, verbessertes b-tagging, multivariate Analysen,…

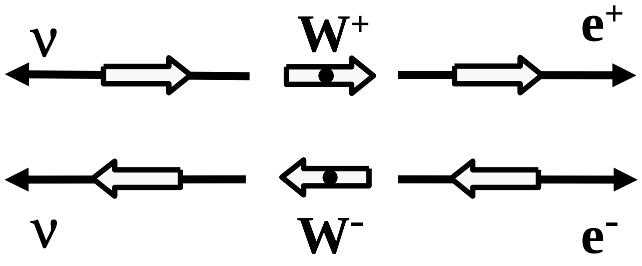


Higgs-Suche am Tevatron

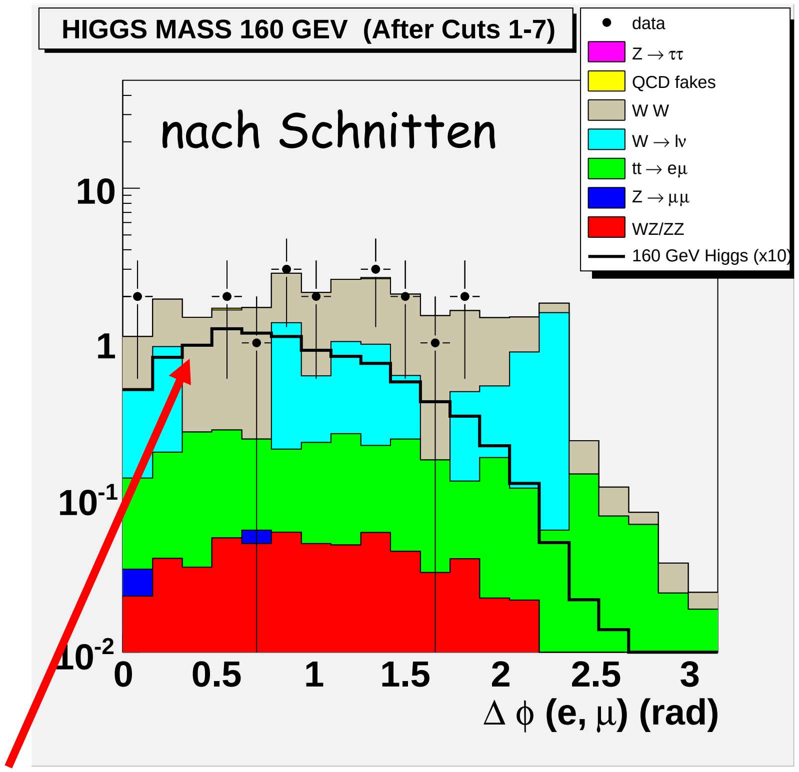
$H\to WW\to l^+\nu l^-\nu$

Keine Massenrekonstruktion möglich
Ausnutzung der ll-Winkelkorrelation

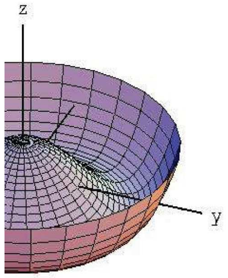
D0 preliminary, 950 pb^{-1}



Leptonen aus H→WW sind
bevorzugt kollinear



SM-Higgs(160) * 10



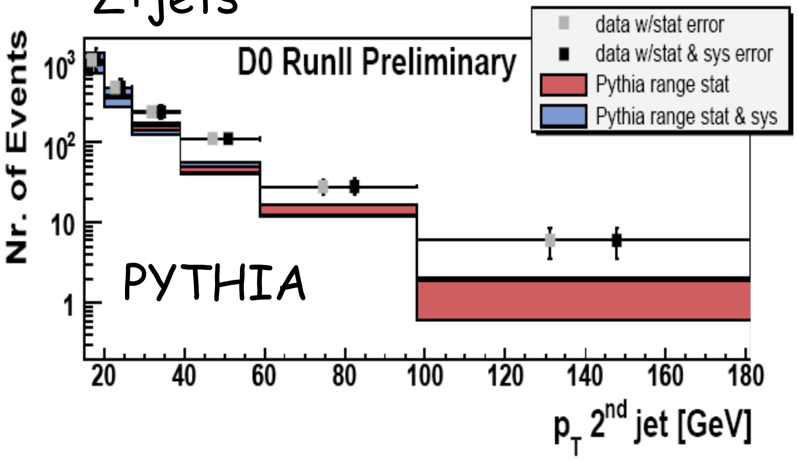
Vom Tevatron zum LHC: Untergründe modellieren

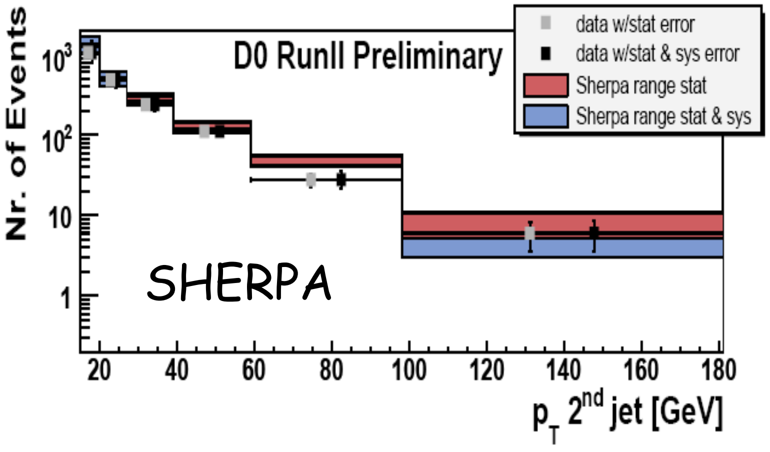
Zum Verständnis der wichtigsten Untergrundprozesse am LHC (Z+jets, W+jets, tt+jets,…) werden Simulationen benötigt, die über LO+Partonschauer hinausgehen.

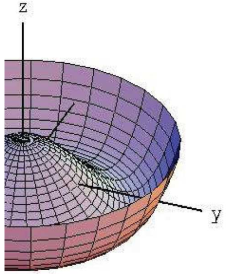
Neue Entwicklungen:
MC@NLO (bis zu 1 zusätzlicher Jet)
ALPGEN, SHERPA (n zusätzliche Jets als LO Matrix-Element,
„matching" von Matrix-Element und Partonschauer

Wichtige Tests am Tevatron:

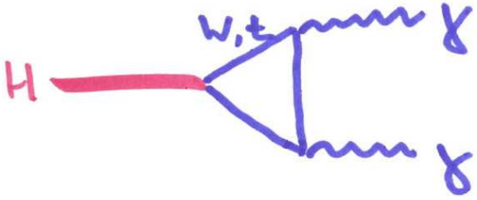
Z+jets

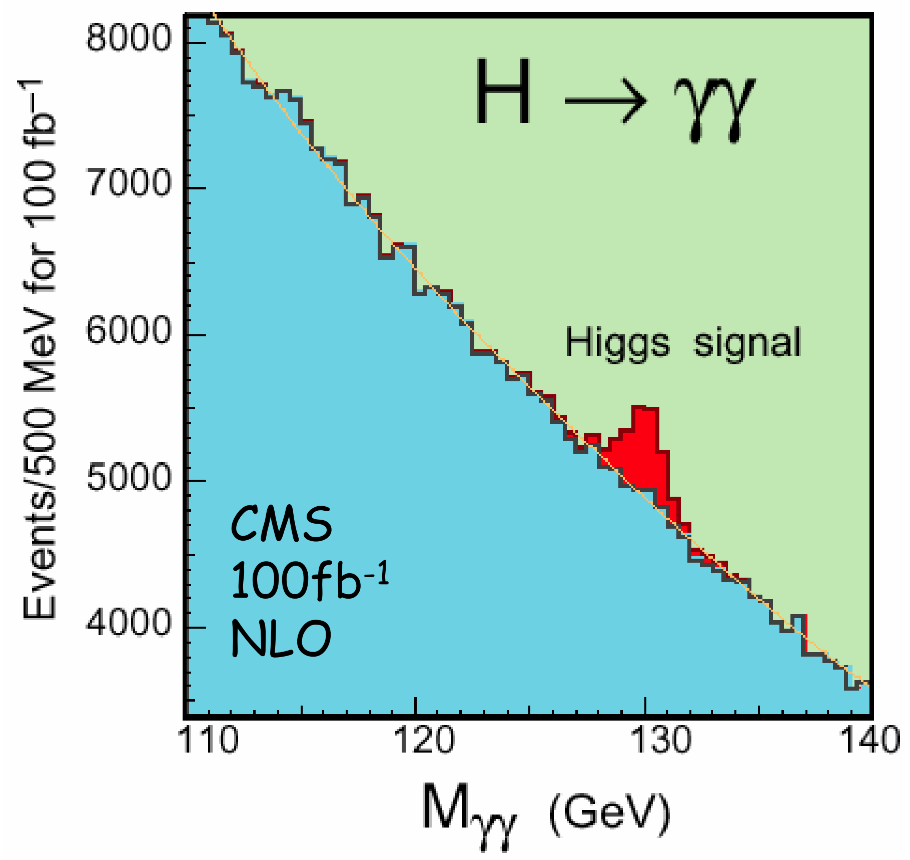






Inklusive Suche nach H→γγ



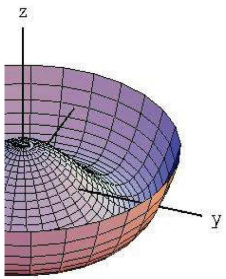


dominanter irreduzibler Untergrund
pp→γγ+X

reduzibler Untergrund
pp→$\gamma\pi^0$ + X
schwer zu berechnen
(Fragmentation, Isolation)

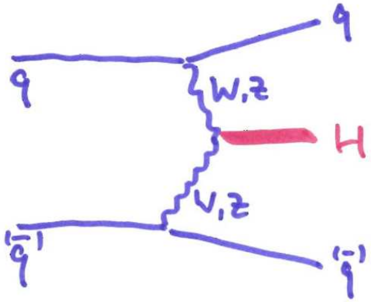
Benötigt optimale Massenauflösung
$\sigma_M/M = 1\%$

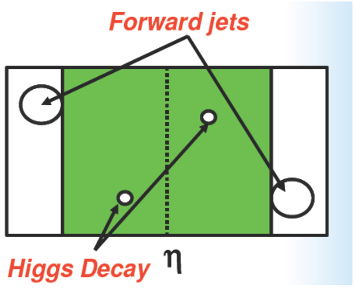
Untergrund aus Seitenband



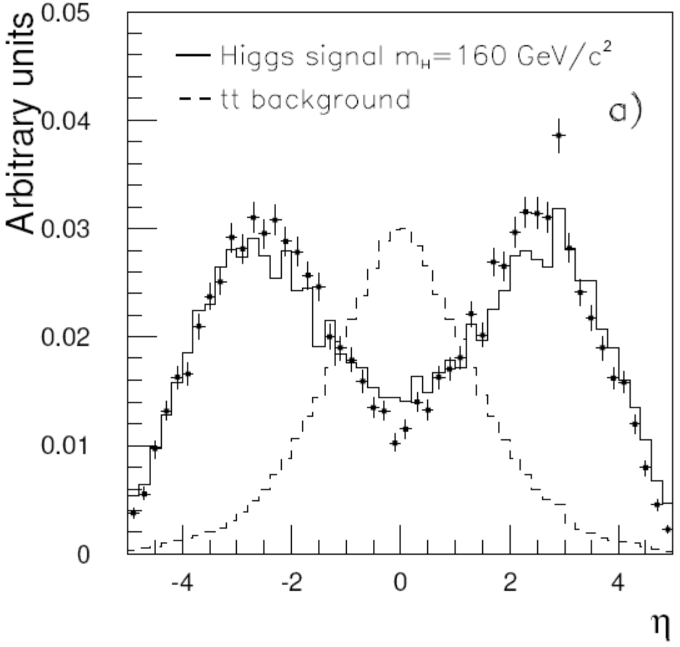
Vektorboson-Fusion

Nach Gluon-Fusion nächstgrößter WQ
Untergrundunterdrückung durch
- Vorwärts-Jets
- Kein Farbfluss im Zentralbereich:
  Rapiditätslücke

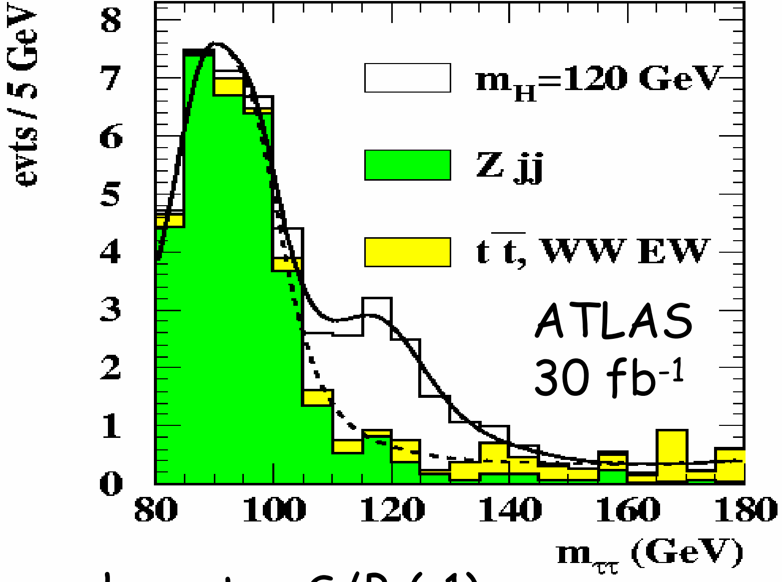




Winkelverteilung der Jets:



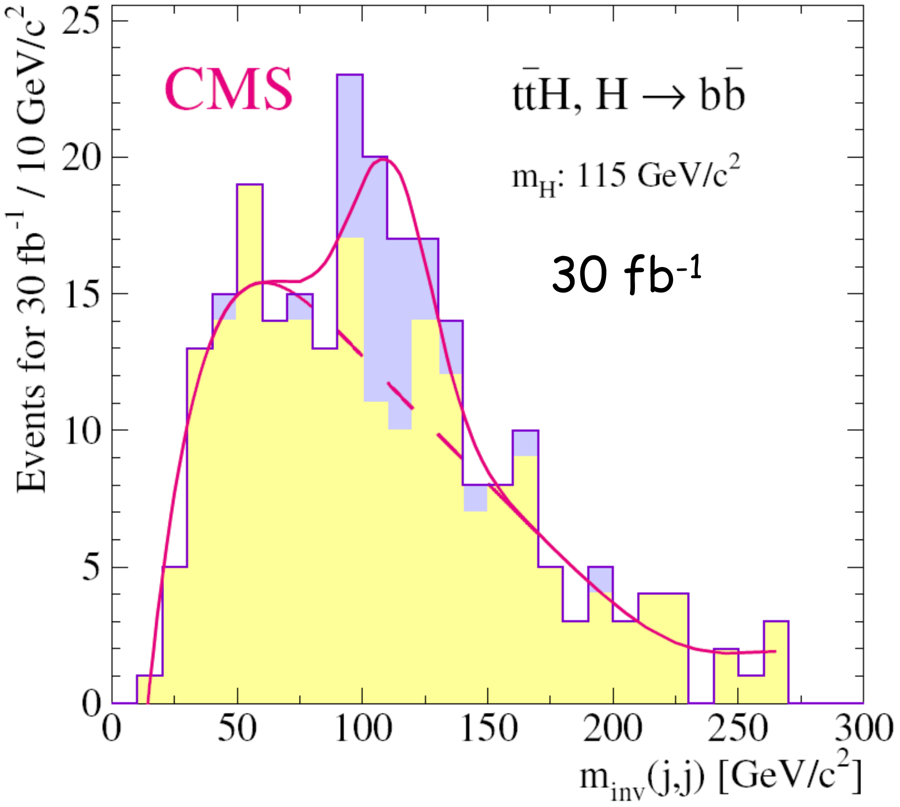
H→ττ→μνν eνν



- sehr gutes S/B (>1)
  kritisch:
- Effizienz der Vorwärtsjet-Erkennung
- zentrales Jet-Veto

Assoziierte top-Higgs-Produktion

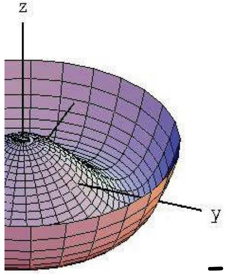
Bislang einziger zugänglicher Kanal im dominanten H→bb-Zerfall
Endzustand: ttH→bWbWbb→blνbjjbb



trägt bei niedrigen m_H
zum Entdeckungspotenzial bei

Zugang zur Top-Yukawa-Kopplung

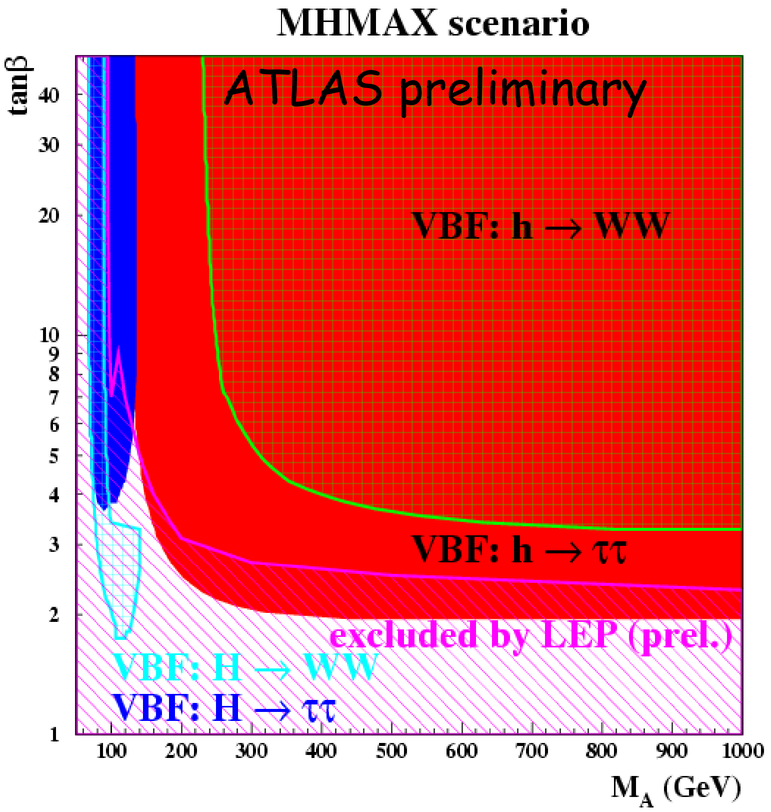
kritisch:
- b-tagging
- tt+jets-Untergrund
- Bestimmung des Untergrundes aus Daten



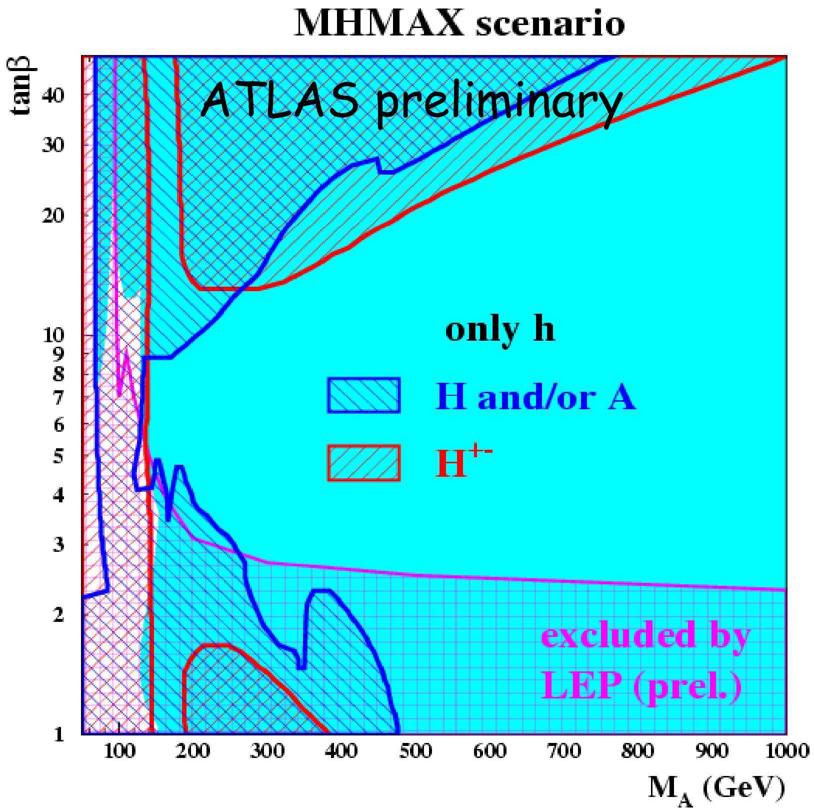
Higgs in SUSY

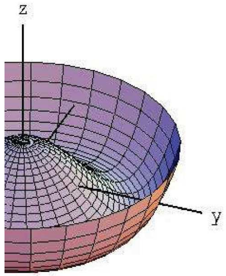
- mindestens ein MSSM-Higgs-Boson kann im gesamten Parameterbereich gesehen werden
- für große tanβ Entdeckung von H/A und $H^\pm$ möglich (H/A→$\tau\tau$,$\mu\mu$,$H^\pm\to\tau\nu$)

VBF, 30fb^{-1}



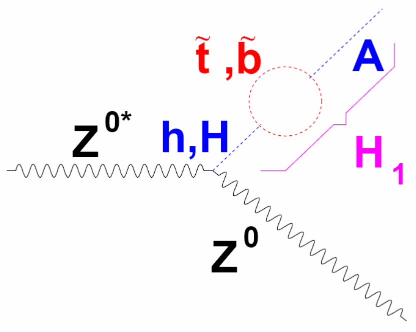
300 fb^{-1}

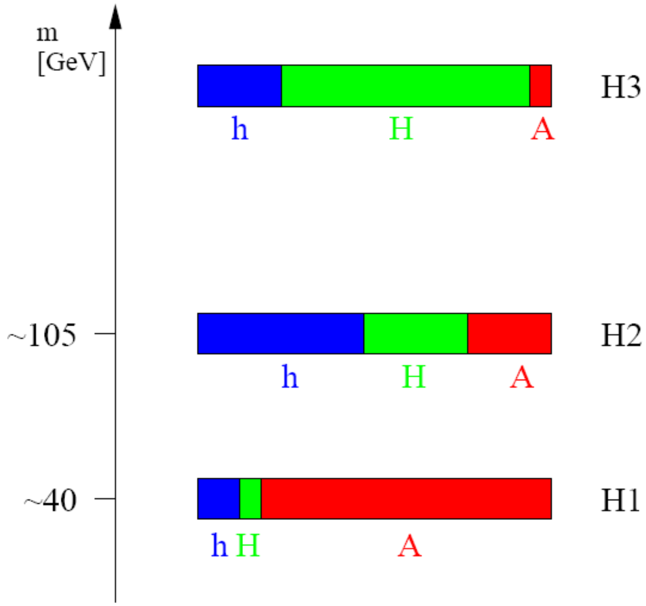


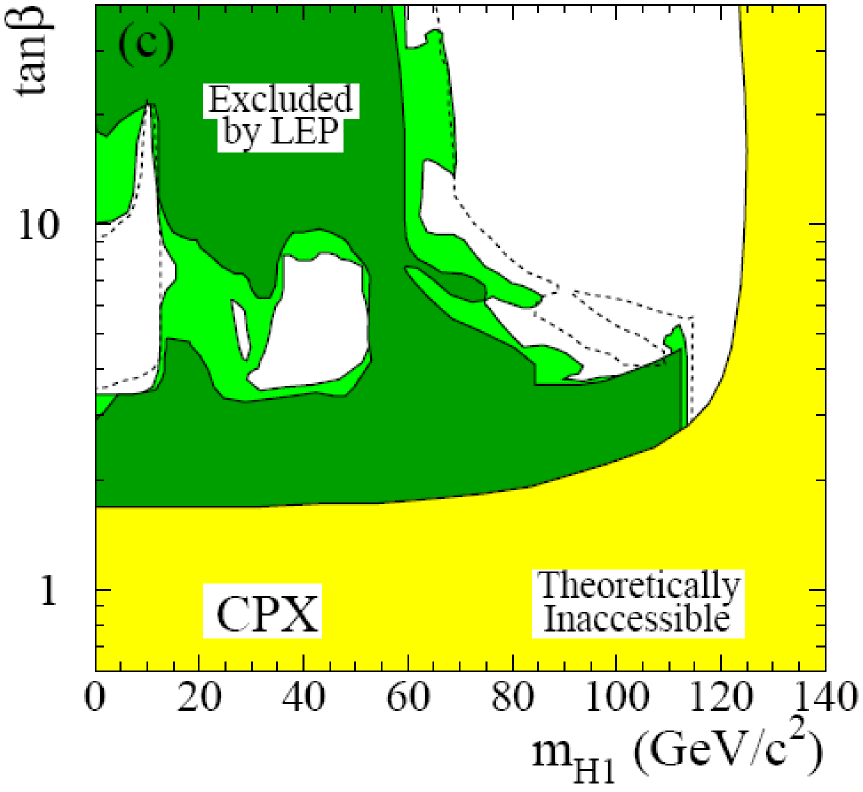


Das Erbe von LEP: Higgs mit CP-Verletzung

Komplexe Phasen in trilinearen Kopplungen können zu Mischung von h,H,A führen:

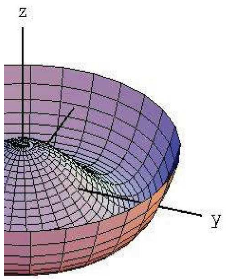






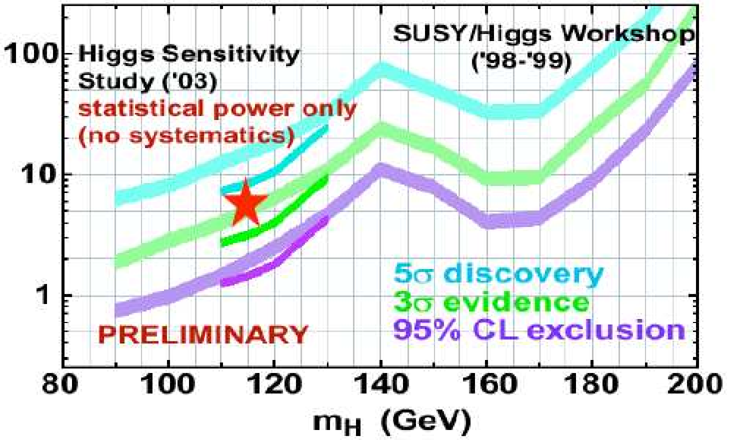
$$m_{\text{top}} = 174.3\ \text{GeV}$$

„Loch" bei kleinen Higgs-Massen!
LHC dort sensitiv?

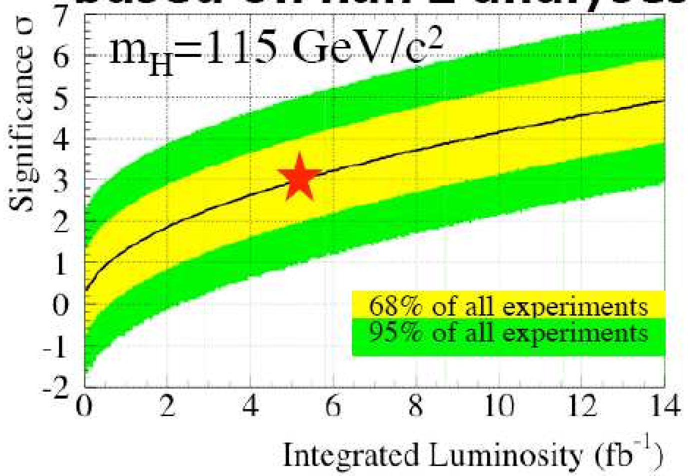


SM-Higgs amTevatron: Erwartungen

based on pre-Run 2 analyses



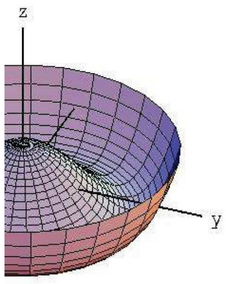
based on Run 2 analyses



- **Confirmed previous studies with run 2 data experience**
  - Syst. uncertainties increase required luminosity by 40%
- **95% C.L. exclusion:**
  - $\int Ldt = 2-2.5\ \mathrm{fb}^{-1}$: probe LEP excess at $m_H = 115\ \mathrm{GeV}/c^2$
  - $\int Ldt = 4.0\ \mathrm{fb}^{-1}$: up to $m_H = 130\ \mathrm{GeV}/c^2$
  - $\int Ldt = 8.0\ \mathrm{fb}^{-1}$: up to $m_H = 135\ \mathrm{GeV}/c^2$

  Severely constrains MSSM
- **3σ evidence:** ★
  - $\int Ldt \approx 5.0\ \mathrm{fb}^{-1}$: for $m_H = 115\ \mathrm{GeV}/c^2$

Beate Heinemann



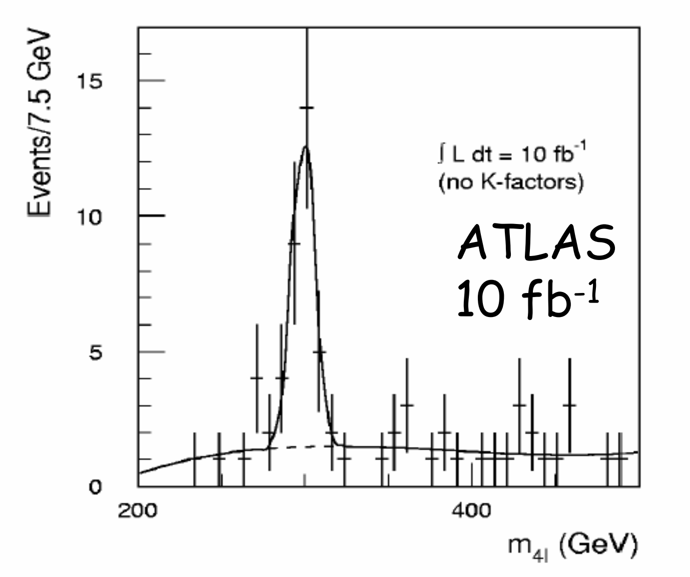
Higgs discovery at the LHC

Vielzahl von Produktionsmechanismen und Zerfallskanälen

- Inklusive Suche nur in Lepton/Photon Endzuständen möglich ($H\rightarrow\gamma\gamma$, $H\rightarrow ZZ\rightarrow 4l$)
- $H\rightarrow bb$ nur in Assoziation mit tt
- $H\rightarrow\tau\tau$ in Assoziation mit Vorwärts-Jets ($qq\tau\tau$)

Nur Endzustände mit Lepton/Photon-Trigger als Entdeckungs-Kanäle

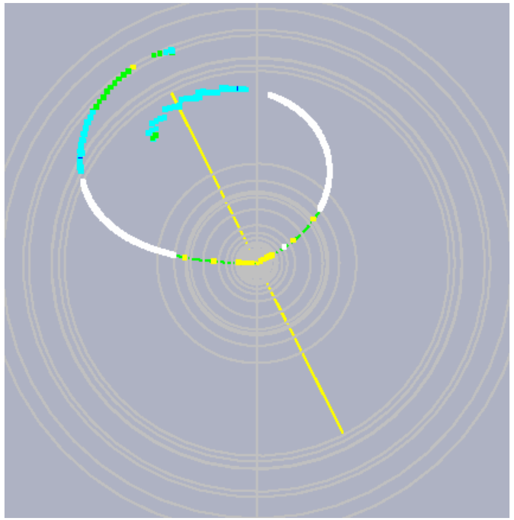
Goldener Kanal für m_H >~ 140 GeV:



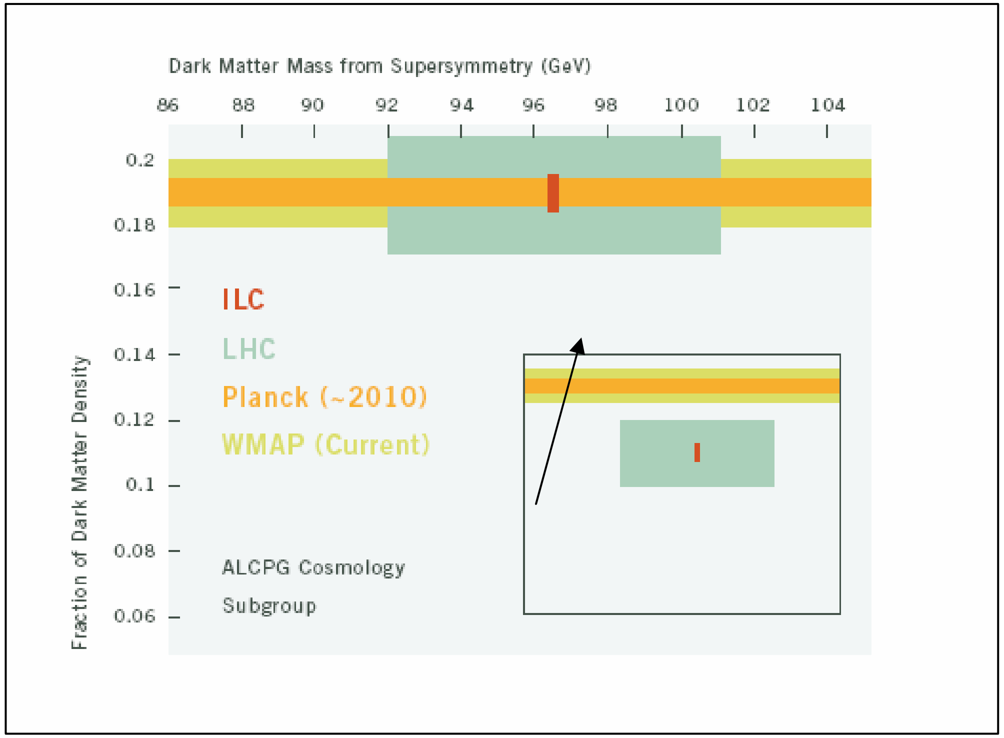
- sehr moderater Untergrund
- $H\rightarrow WW\rightarrow l\nu l\nu$ hat höhere Rate, aber keine Massenrekonstruktion (nicht ideal für Entdeckung)
- benötigt 3-4 fb^{-1} für Entdeckung (m_H>180 GeV oder m_H=135-155 GeV)

Why does it matter?

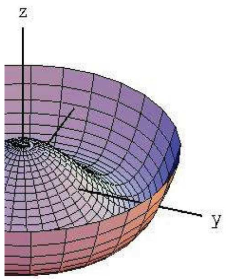
Forward hermeticity:



muons at 1 TeV from smuon pair production

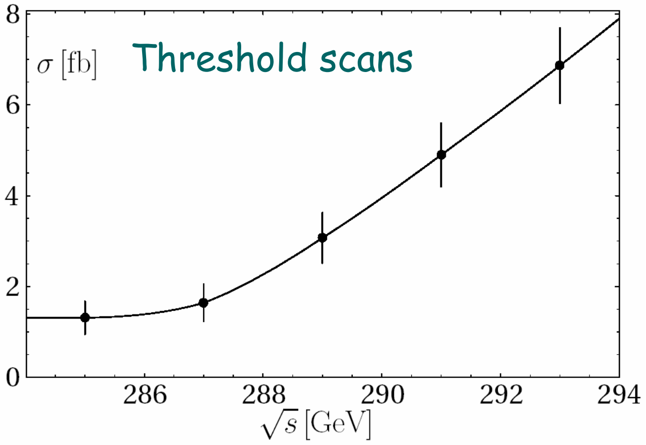


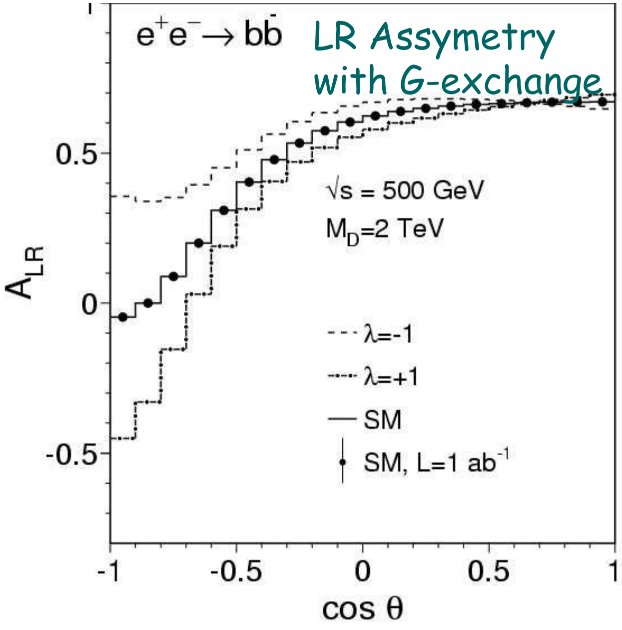
If we talk about ‘cosmic connections’ we have to talk about beamstrahlung, crossing angles, rad-hard calorimeters and all that…



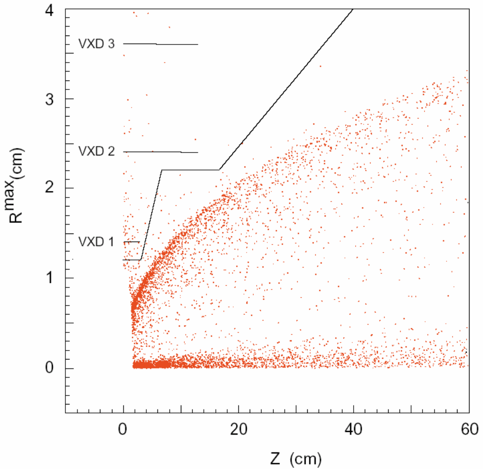
Why does it matter?

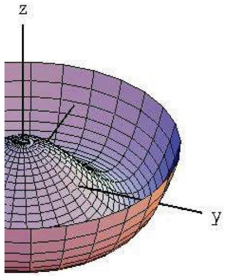
Precise measurement of
Luminosity (spectrum),
Beam Energy
Polarisation
has direct impact on the physics





MDI – Cope with backgrounds





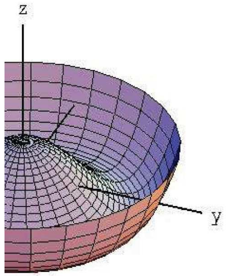
R&D infrastructure

In the coming years, intensive test-beam program is needed

Apart from the beams themselves a common infrastructure for measurements of individual groups is needed

- Large Bore Magnets
- Beam telescopes
- 'Universal' calorimeter stack
- 'Universal' TPC field cage
- ...

Recent success in providing such infrastructure: EUDET



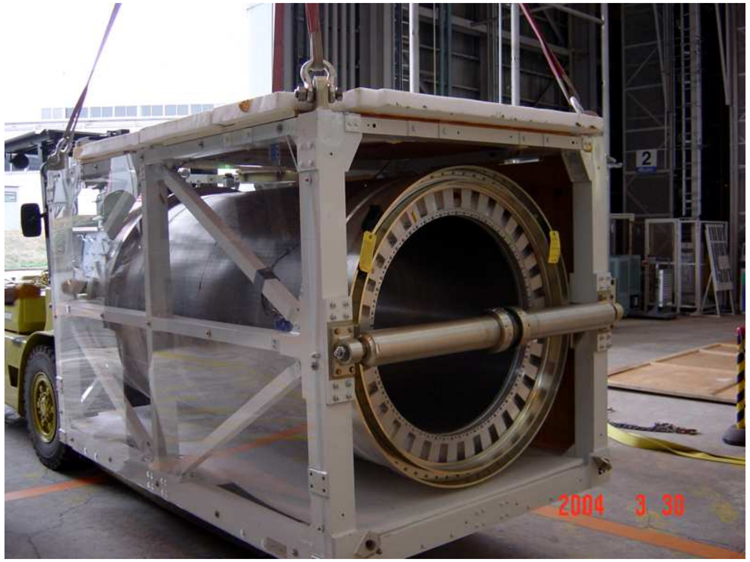
EUDET

EU funded 4-year program ('Integrated Infrastructure Initiative')
to improve infrastructure for ILC detector R&D
total budget 21.5M€, EU-funded: 7M€

Coordinating Lab: DESY – Participants from all over Europe
Magnet from Japan (good example… more of that, please)

Workpackages on

- Testbeam Infrastructure
- Tracking Infrastructure
- Calorimetry Infrastructure
- Common tasks (Software,
  Computing,
  Chip-Design)



This infrastructure is open to the world!