# CMS at LEP3

Markus Klute (MIT) for the CMS LEP3 team

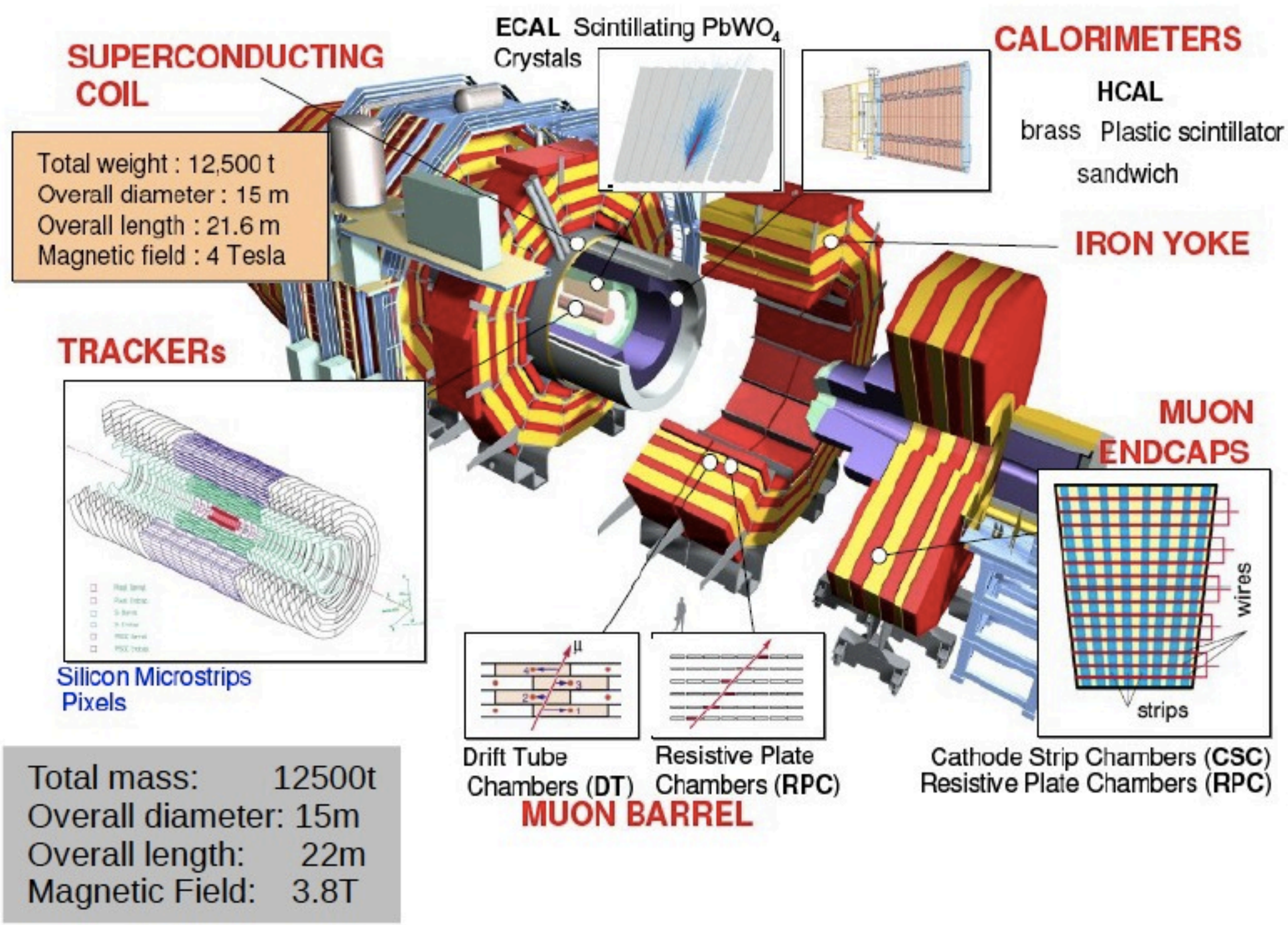
LEP 3 Workshop

June 18th, 2012

# CMS at LEP3

- Working group
  - P. Janot, P. Lenzi, L. Malgeri (CERN)
  - M. Klute, M. Zanetti (MIT)
  - not a “CMS collaboration” effort
- What are the goals
  - feasibility study of CMS as LEP3 detector
  - perform key Higgs analyses
  - estimate precision on Higgs property measurements
  - there is more to the LEP3 physics program, not considered here
    - W mass, giga Z, etc. (see Patrick’s talk)
- Timeline
  - kick-off meeting Mar. 22nd, 2012
  - regular meetings
  - submit paper for European Strategy group

# CMS

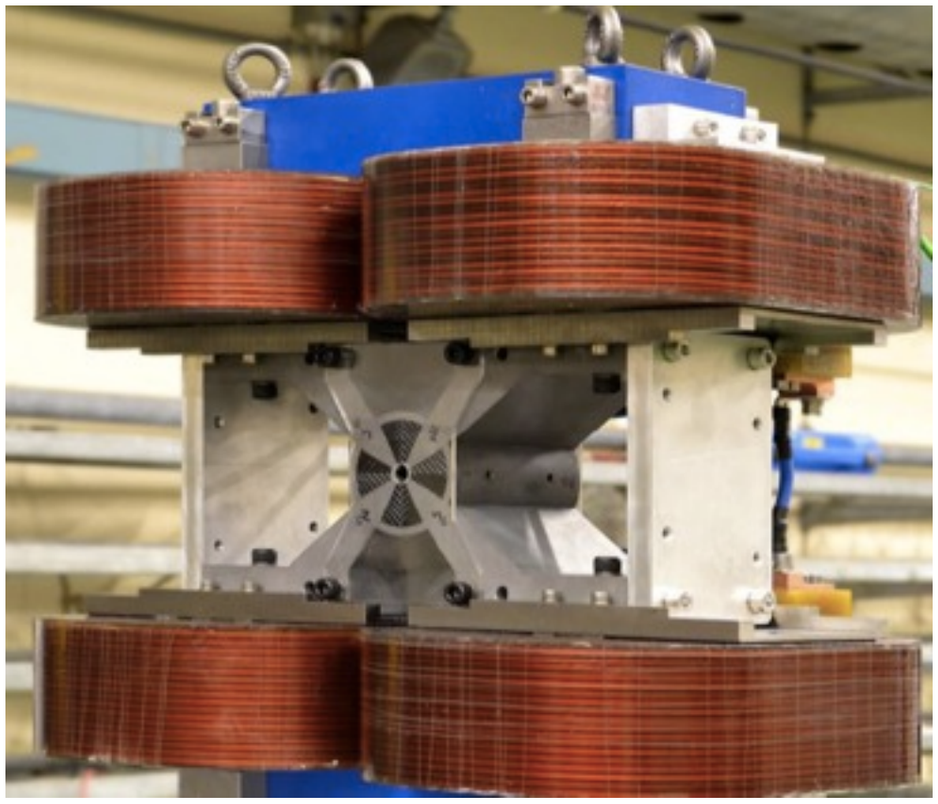



Total mass: 12500t
Overall diameter: 15m
Overall length: 22m
Magnetic Field: 3.8T

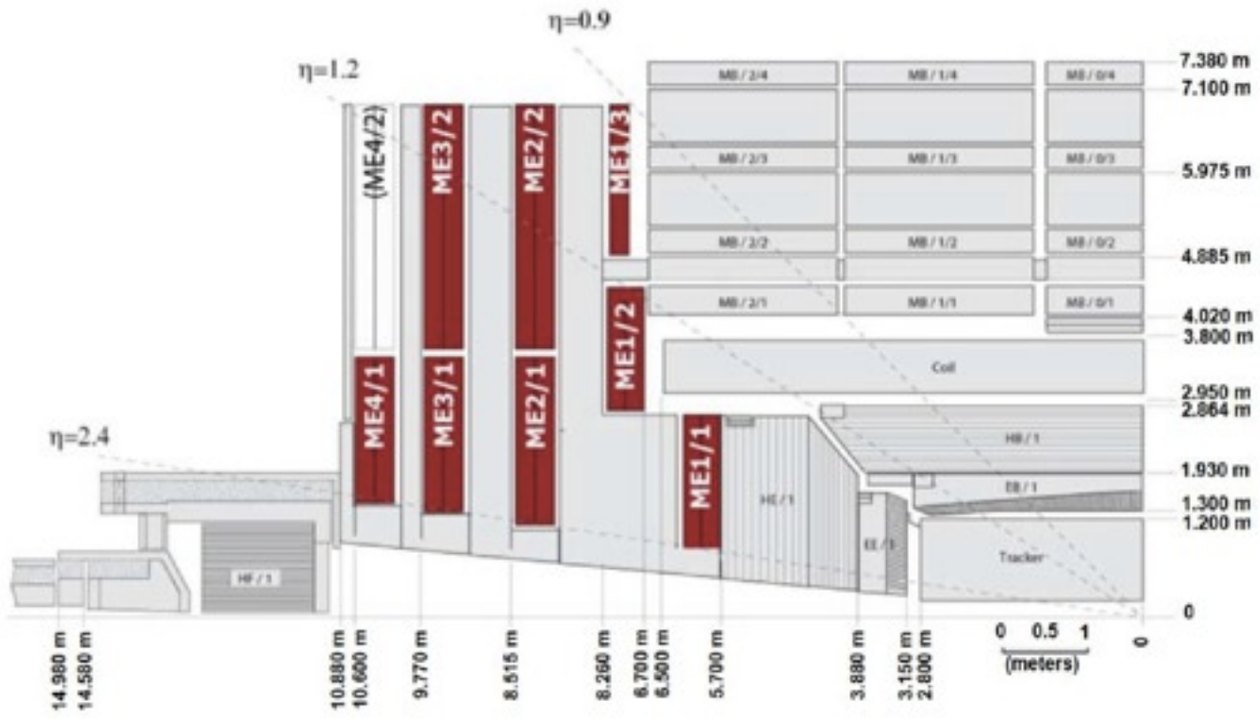
# CMS Final Focus

- Focusing quadrupole magnets have to be installed very close to the interaction point, ~4m.
- LEP3 requires requires 17T/m gradient, with an aperture of 5cm corresponding to about 20 σ
- Very small prototype magnets have been produced at CERN already

### 500 T/m CLIC



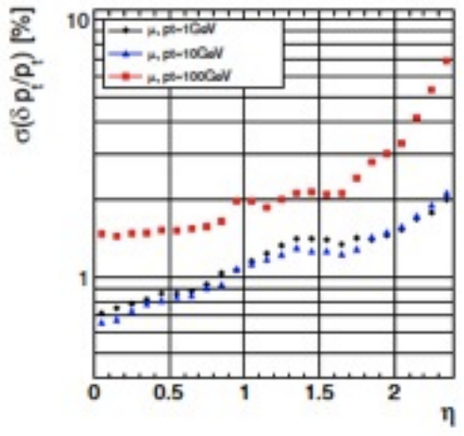
### CMS longitudinal view

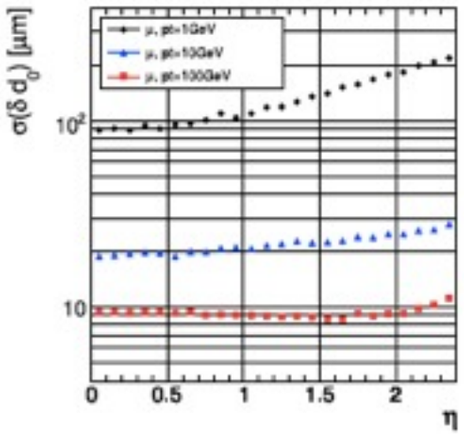



HF can be moved in parking position

# CMS Performance

- **Comparing CMS with typical LC detector.**
  - **good enough for Higgs program?**
- **Momentum**
  - $\sigma_{pT}/pT = 0.7\%$ (10 GeV, central)
- **Jet energy**
  - $\sigma_E/E \sim 13\%$
- **Impact par.**
  - $\sigma_{d0} = 20\mu m$ (10 GeV, central)



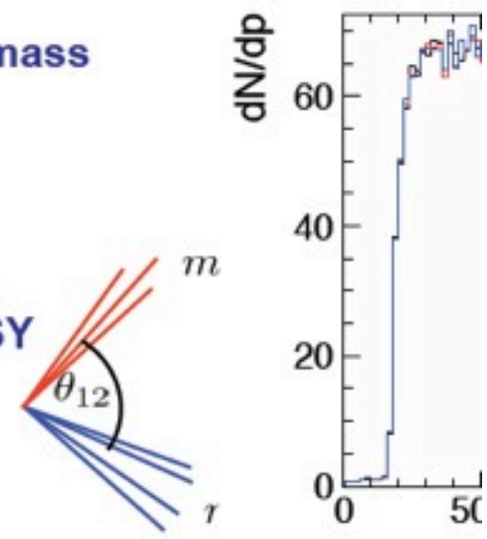




★ **momentum:** (1/10 x LEP)
e.g. Smuon endpoint, Higgs recoil mass

$$\sigma_{p_T}/p_T^2 \sim 2\times 10^{-5}\,\mathrm{GeV}^{-1}$$

★ **jet energy:** (1/3 x LEP/ZEUS)
e.g. W/Z di-jet mass separation, SUSY

$$\frac{\sigma_E}{E} \sim 3.5 - 5\,\%$$




★ **impact parameter:** (1/3 x SLD)
e.g. c/b-tagging, Higgs BR

$$\sigma_{r\phi} = 5 \oplus 15/(p[\mathrm{GeV}]\sin^{\frac{3}{2}}\theta)\,\mu\mathrm{m}$$

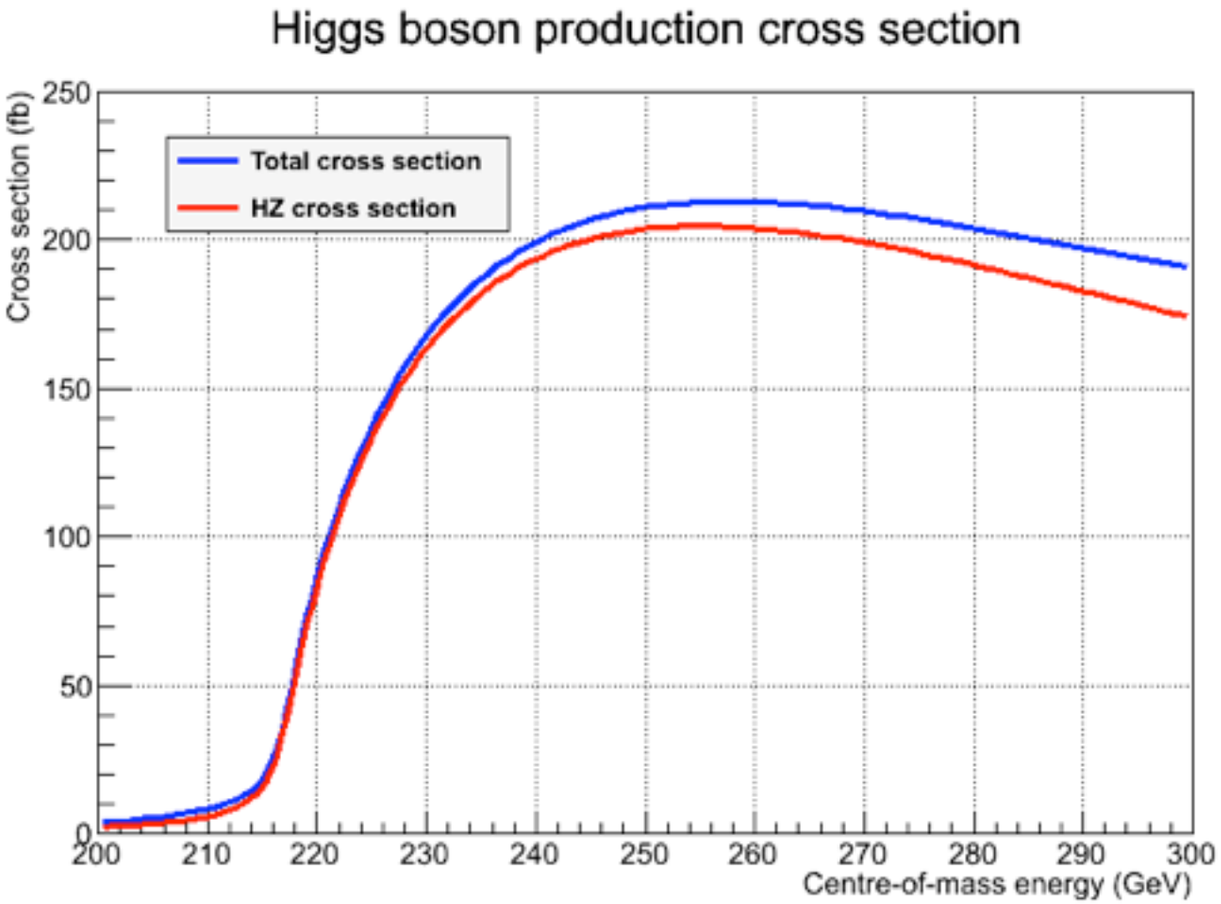
★ **hermetic:** e.g. missing energy signatures in SUSY

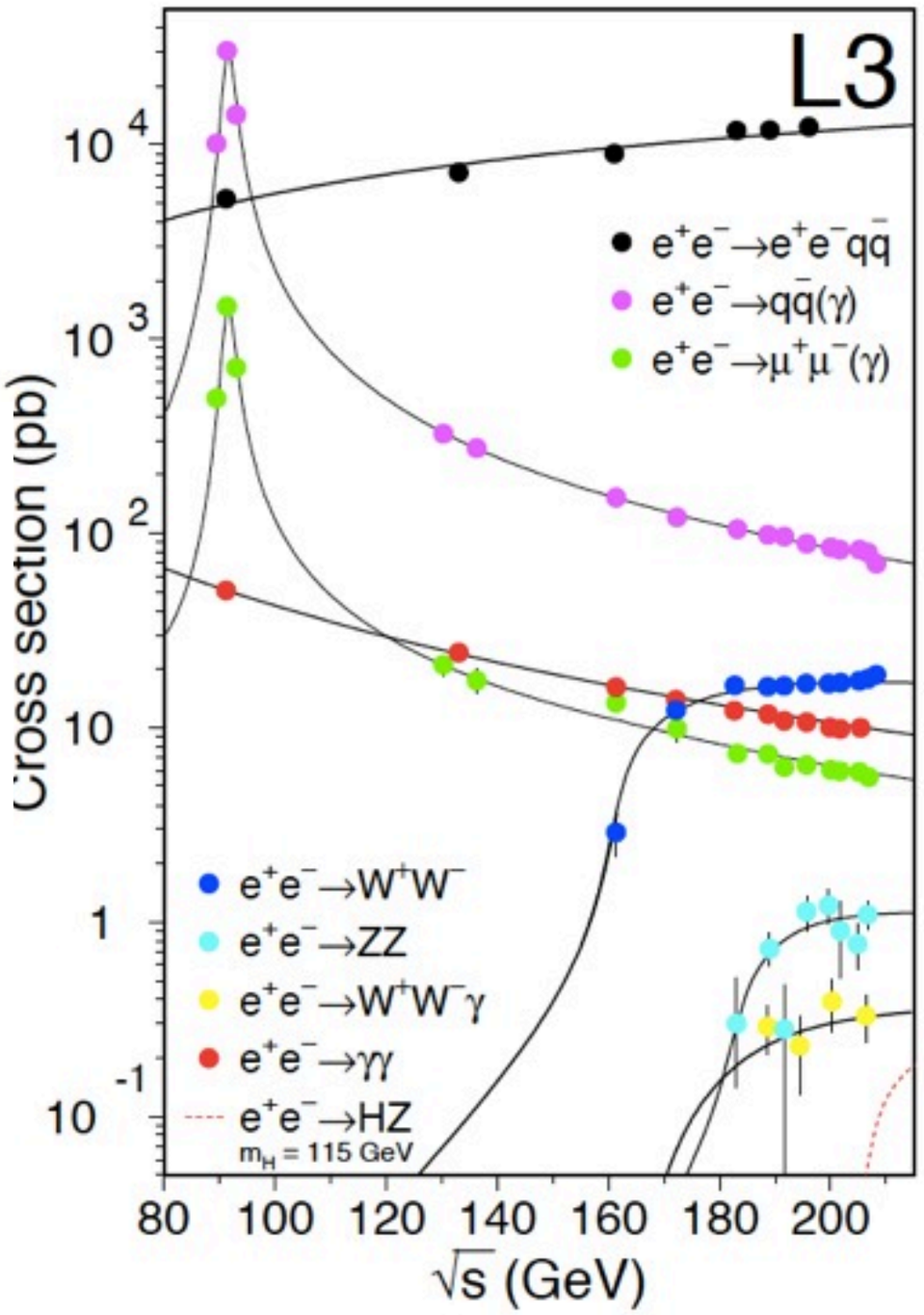
★ **granularity:** in space and time to mitigate background

**from Mark Thomson (CERN-PH Seminar)**

# Assumptions for Physics Studies

- SM-like Higgs at mH = 125 GeV
- e+e- collider with sqrt(s) = 240 GeV
- Higgs cross section ~200fb
- Study physics potential with 500/fb
  - L ~1e34 / cm^2s, 20000 Higgs bosons / year



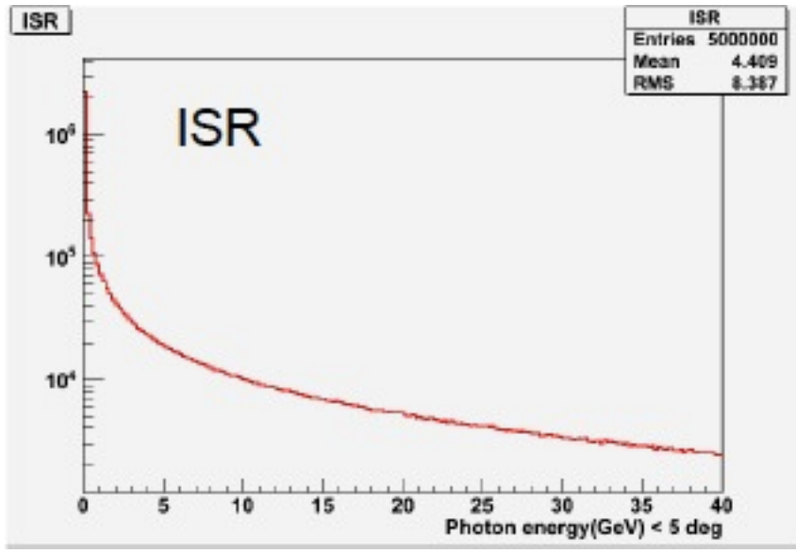
# Simulation

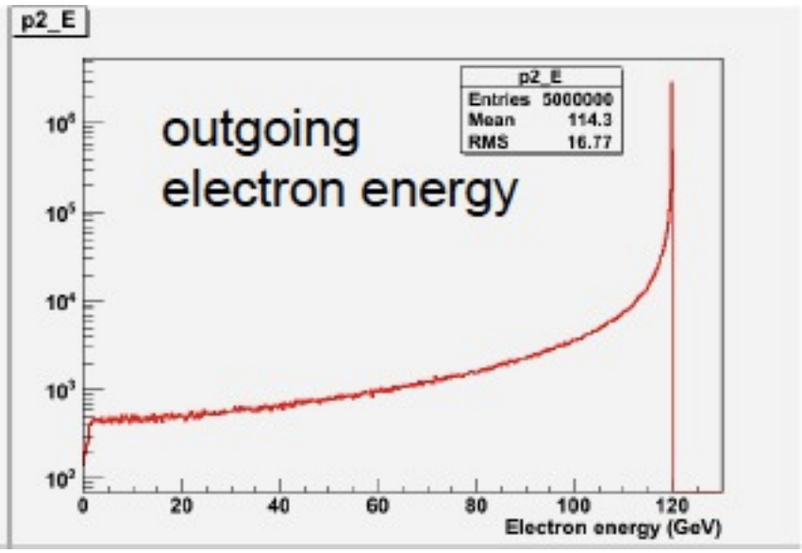
- Full simulation for current CMS detector
  - timeline for LEP3 is such that CMS will be upgraded
- Forward hadronic calorimeter will have to be removed (parked)
  - kept in the simulation, but information is ignored
- Run standard CMS simulation and reconstruction
- Pythias for background processes and HZHA for the signal
  - comparisons with Whizard (ILC default MC program)

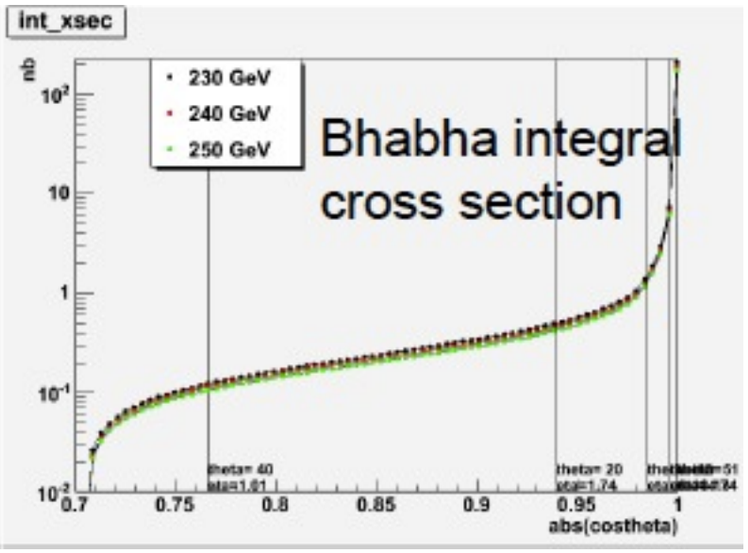
| Process | Cross Xsec [fb] | events in 500/fb | events produced | AOD size [GB] | RECO size [GB] | CPU [h] | slot [8h] |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| W+W- | 16,000 | 8,000,000 | 2,000,000 | 78.20 | 291.82 | 6,667 | 833 |
| ZZ | 1,300 | 650,000 | 1,000,000 | 39.10 | 145.91 | 3,333 | 417 |
| Zh | 200 | 100,000 | 100,000 | 3.91 | 14.59 | 333 | 42 |
| qqbar(gamma) | 50,000 | 25,000,000 | 6,000,000 | 234.60 | 875.47 | 20,000 | 2,500 |
| mumu(gamma) | 4,200 | 2,100,000 | 500,000 | 19.55 | 72.96 | 1,667 | 208 |
| tautau(gamma) | 4,200 | 2,100,000 | 500,000 | 19.55 | 72.96 | 1,667 | 208 |
| ee(gamma) | 4,200 | 2,100,000 | 500,000 | 19.55 | 72.96 | 1,667 | 208 |
| | | | | | | | |
| | | 40,050,000 | 10,600,000 | 414.47 | 1,546.67 | 35,333 | 4,417 |

# ISR and Bhabha

- BHLumi used to estimate impact of ISR and Bhabha scattering on the physics performance
- ISR corresponds on average to 2% of sqrt(s)
- Rate of detectable electrons/positrons:
  - small and will not impact physics
  - large enough to measure luminosity

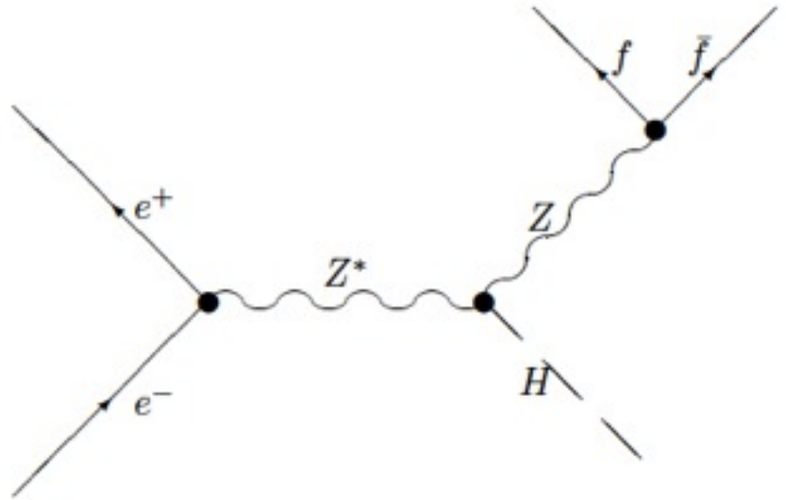


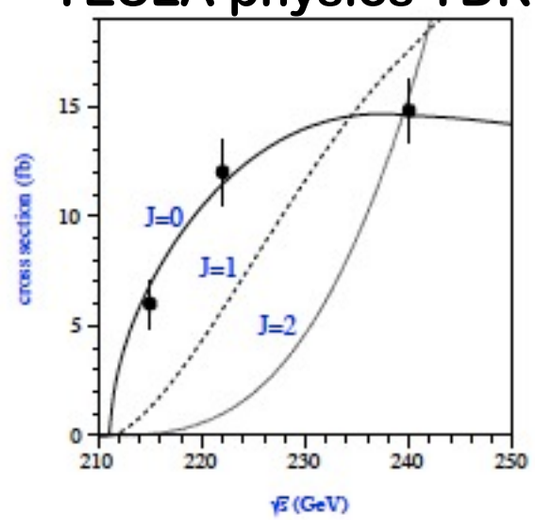



# Recoil Method

- Higgs-strahlung with Z → ll allows decay mode independent measurement
  - performed on OPAL data (Eur.Phys.J.C27:311-329,2003)
  - benchmark for linear collider studies
  - sensitive  Higgs to invisible
  - large Higgs width
  - many mass degenerate Higgs state
- Mass
  - can also be measure model dependent
- Coupling
  - model independent extraction of gZZH from σZH in fit to recoil mass spectrum
- Spin
  - using sqrt(s) scan
- CP properties
  - using angular distributions
  - test Mzϕ = MZH + MZA

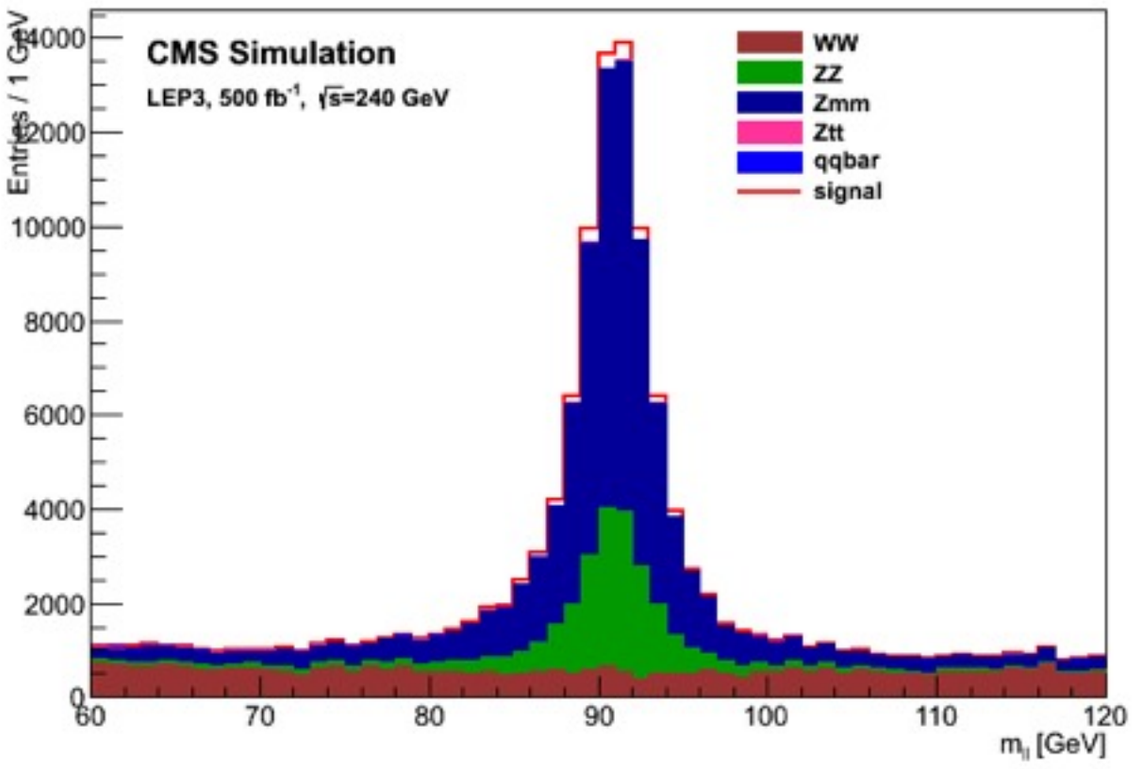


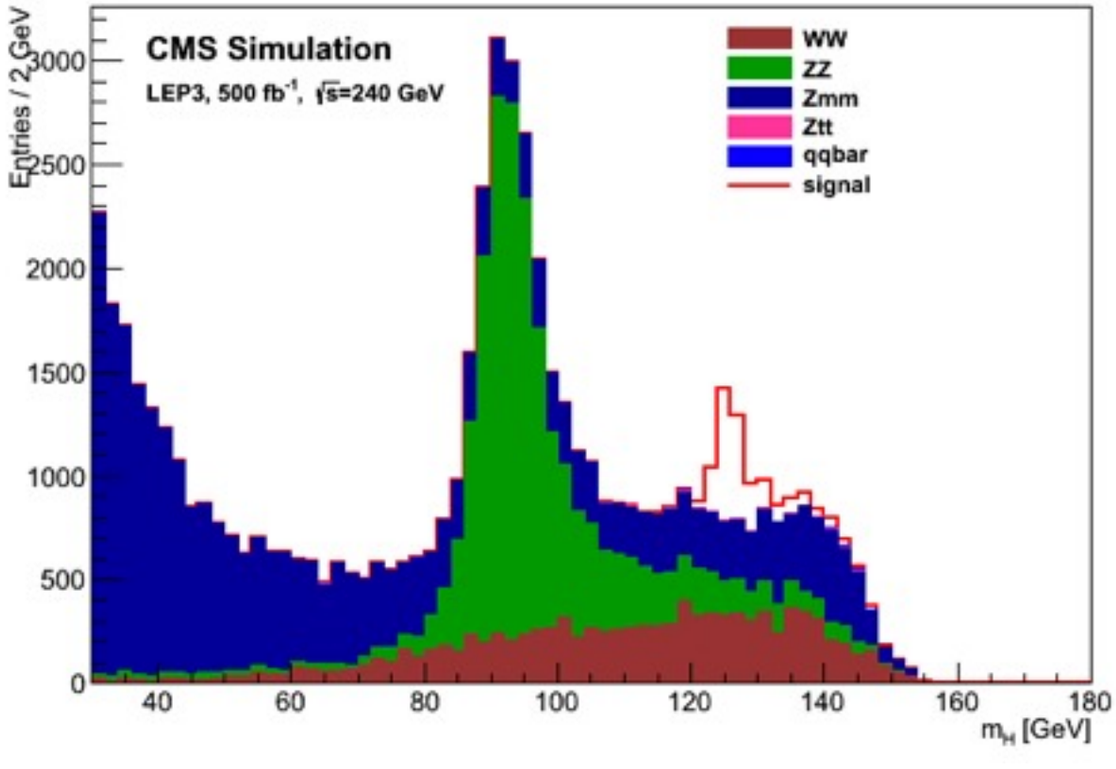

TESLA physics TDR



# Recoil Method

- Selecting two muons, mZ +/- 10 GeV
- Apply additional cuts (di-l pT and Δϕ) to reject Z → μμ and Z → ττ
- More cleanup necessary
- Mass resolution can be improved by recovering FSR



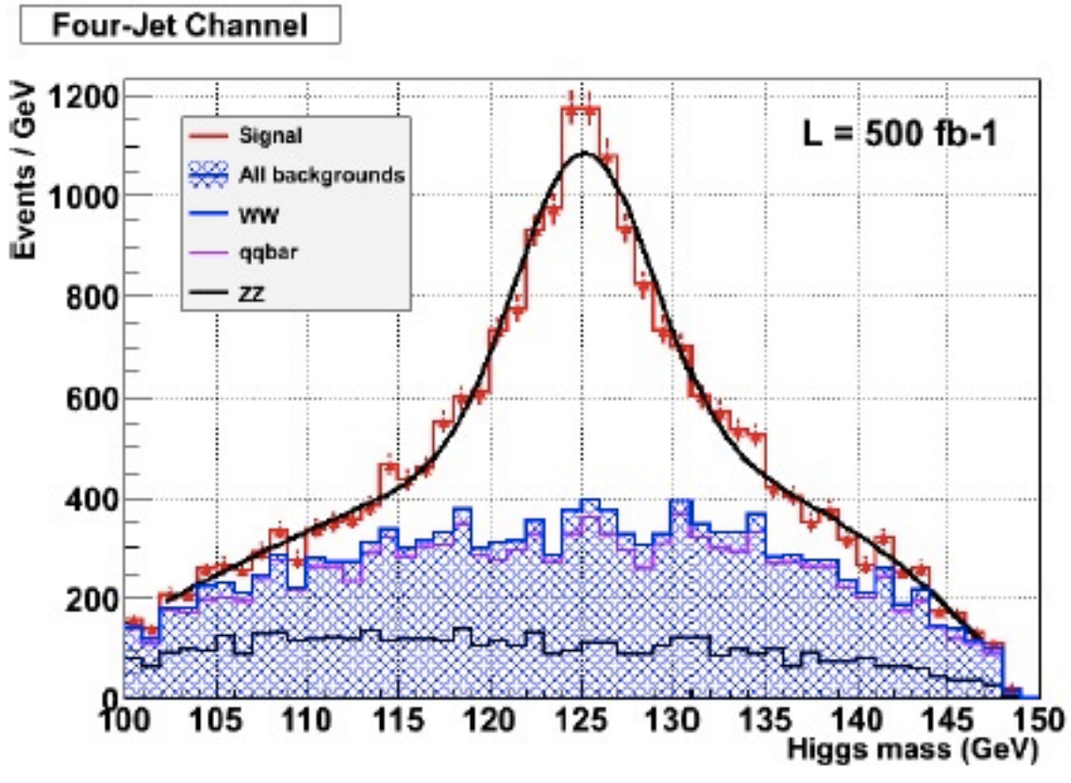

- 3% statistical uncertainty on cross section can be achieved

# Four jet analysis

- Aiming at measuring Higgs to b coupling
- 40% of the total SM Higgs production cross section
- Kinematic selection
  - anti-kT particle flow jet, number of jets >= 4
  - for $N_{Jets} > 4$, recombined the jet pair with the smallest mass
  - $M_{tot} > 180$ GeV
  - fix jet direction p/E, and rescale jet energies to conserve energy (240 GeV) and momentum (0,0,0), and require all rescaled energies to be positive
  - reject WW and ZZ: sqrt((m12-mV)^2+(m34-mV)^2) > 10 GeV, for all 12, and 34 combinations
  - $m_{12} > 100$ GeV (Higgs candidate), $80 < m_{34} < 110$ GeV (Z candidate)
  - resolve ambiguity by selecting on b-tag values of the jets and require b1+b2 > 0.95 (value of secondary vertex tagger)
- Fit a Gaussian + 3rd order pol to $m_{12}+m_{34}-m_Z$

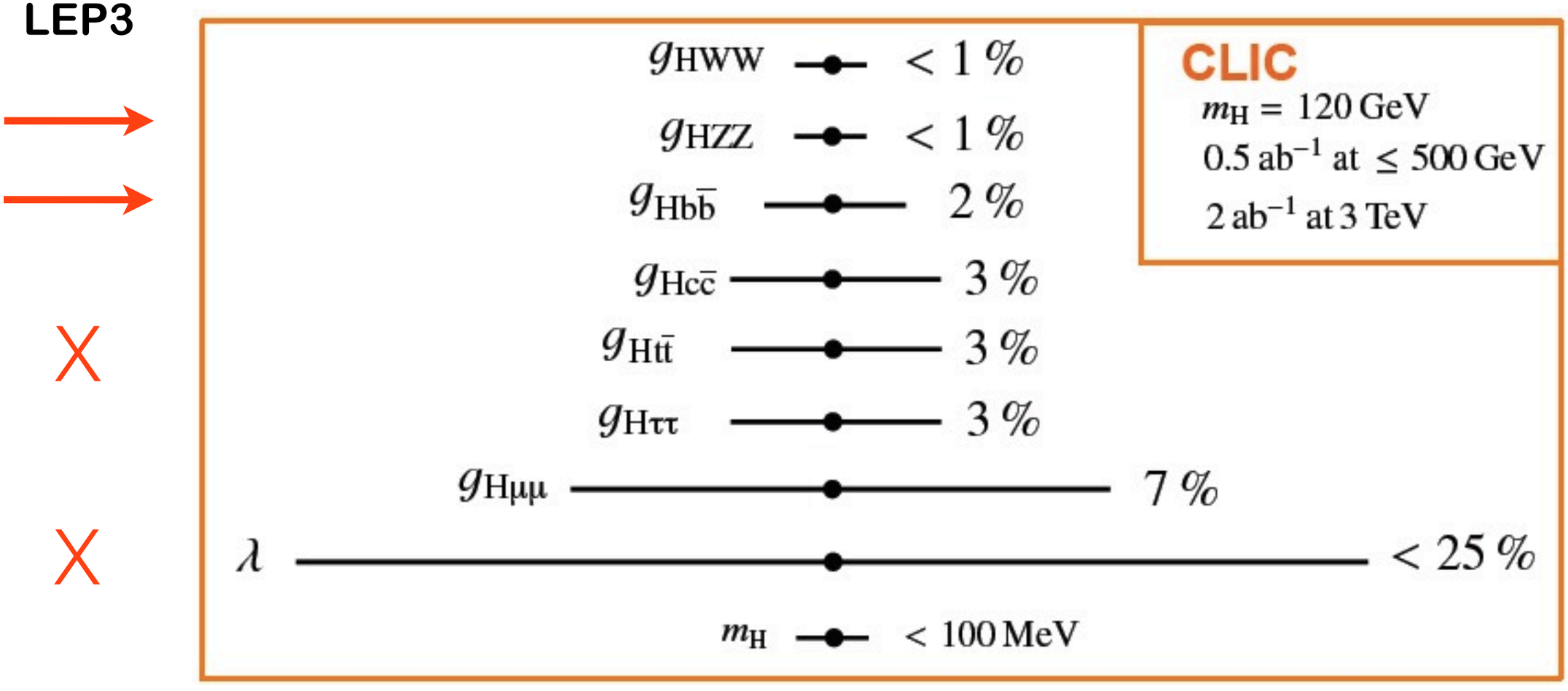
# Four jet analysis

- Higgs mass resolution = 3.7 GeV, mH measured at 100 MeV level
- 2.5% accuracy of fit for cross section, with 500/fb
- Many possible improvements, e.g.:
  - fit of the final state instead of a simple jet rescaling
  - upgraded pixel detector to increase b-tagging efficiency
  - MVA instead of sequential cuts
  - relax seeding for the tracking (tuned for 30PU events)



# Comparison with dedicated LC detectors

LEP3




- CMS@LEP3 show comparable results where measurement is possible

# Short term plans

- Refine recoil analysis
  - FSR recovery
  - selection
  - add electron channel
- Add dedicated Higgs measurement
  - qq$\tau\tau$
  - missing energy channel
  - Higgs to invisible
  - and others

# Summary

- LEP3 is a proposal for high lumi e+e- circular collider in the LHC tunnel
  - Higgs factory with 20000 events per year
- Formed working group to study CMS at LEP3
  - focus in Higgs physics program
  - started with recoil analysis and four jet channel
    - more measurements will be added
- No show-stopper found so far
- CMS is an excellent  e+e- detector
  - performance for Higgs physics comparable to ILC results
- Plan to submit paper to European Strategy group