Top-Quark Physics at the International Linear Collider

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on behalf of the ILC IDT

ilc international development team

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The International Linear Collider

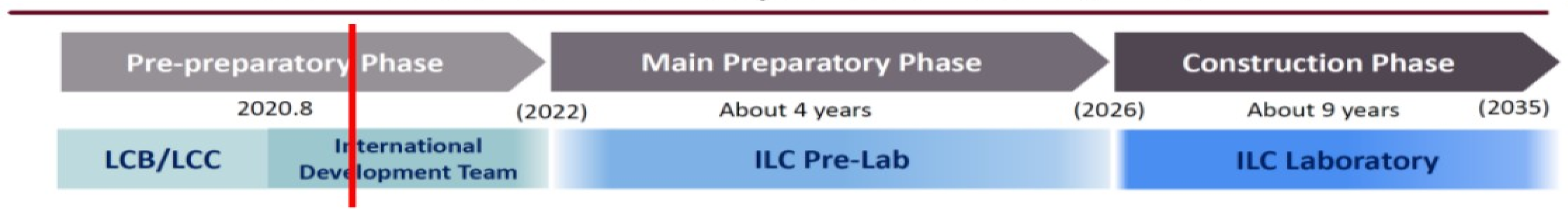
- Energy: from Z-mass to (at least) 1 TeV
- Electron and positron polarization
- TDR in 2013
- + DBD for detectors
- Initial Energy 250 GeV – Footprint ~20km

https://linearcollider.org/

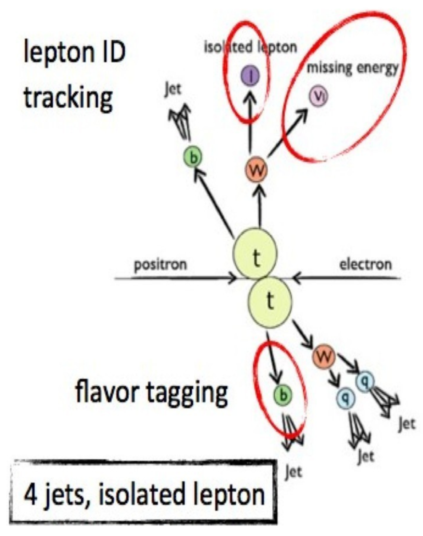
- **Lepton – lepton interactions (no PDFs involved)**
- **All SM particles within reach of the ILC project**
- High precision tests of the SM over wide range to detect onset of new physics
- Machine **settings can be "tailored"** for specific processes → **straightforward at the ILC**
  - **Center-of-Mass energy**
  - **Beams polarization** (±80% e⁻, **±30%e⁺**)
- **Triggerless operation:** 100% of the interactions will be recorded.

Under discussion in Japanese Government and international community

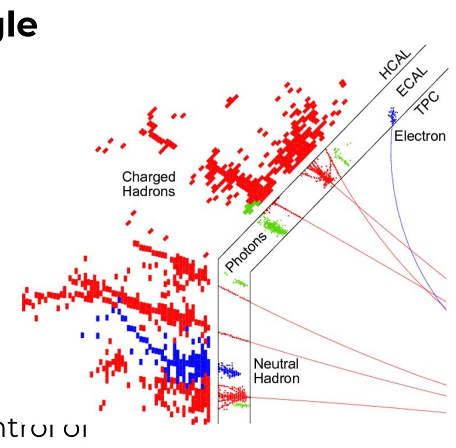
International Development Team (IDT)

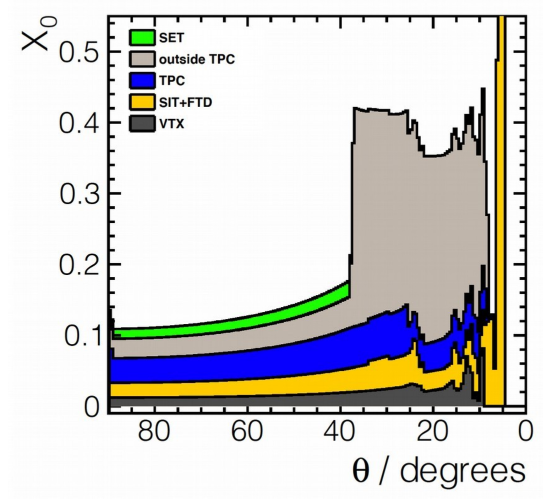


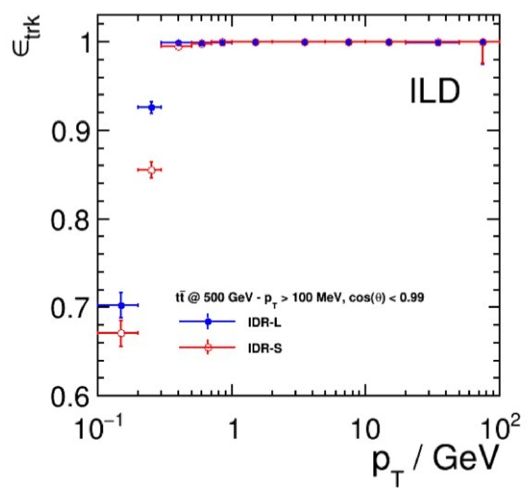
Experimental capabilities

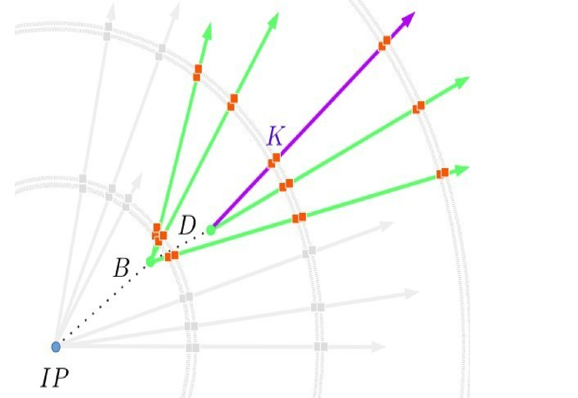


- **High efficient jet reconstruction and single particle separation Particle FLOW .**
  - ~3% energy resolution
- **Excellent tracking capabilities (>99% efficiency)**
- **Excellent Flavor tagging**
  - **Bottom and charm**
- **Quark charge measurements**
  - Vtx charge and Kaon Identification. High purity → control of the migrations
  - High efficiency **(double tagging)**







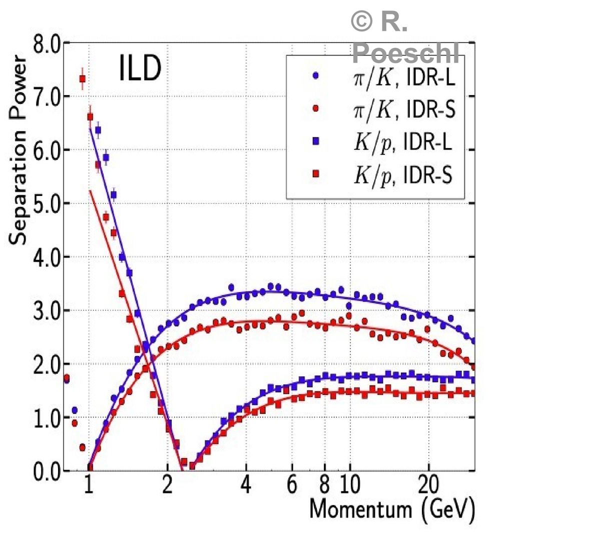


Why this luxury ?

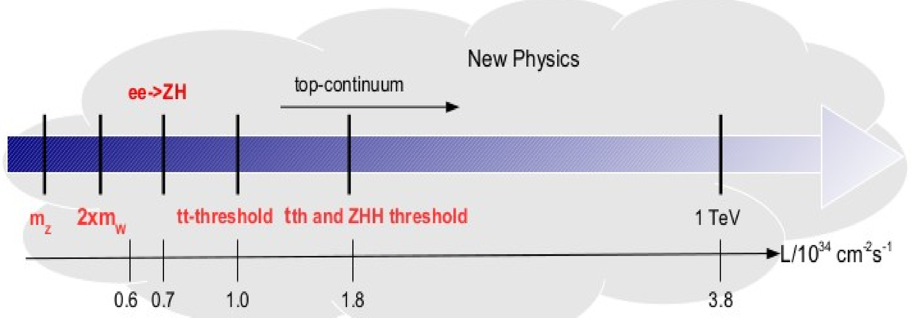
- ILC offers tiny beam spot.
- Tracking detector technologies are in continuous evolution since LEP.
- First vertexing layer at ~1.6cm distance of the beam pipe.
- Minimum dead material (no cooling systems)

	FCCee	ILC	SLC	LEP
σx[nm]	13700	516	1500	200000
σy[nm]	36	7.7	500	2500

Source SLC, LEP, PDG



Top quark production at ILC

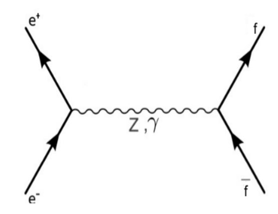


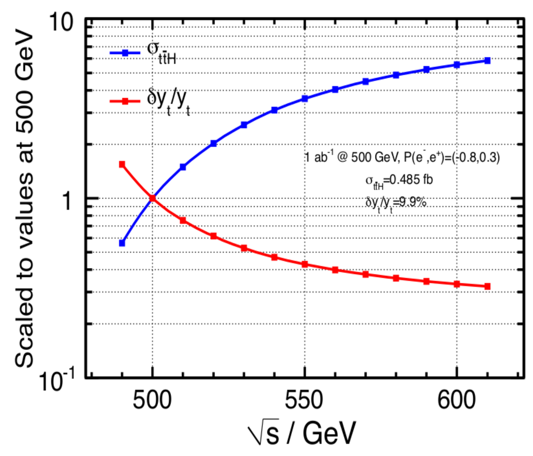
Differential cross sections for (relativistic) di-fermion production*:

$$\frac{d\sigma}{d\cos\theta}(e^-_L e^+_R \to f\bar{f}) = \Sigma_{LL}(1+\cos\theta)^2 + \Sigma_{LR}(1-\cos\theta)^2$$

$$\frac{d\sigma}{d\cos\theta}(e^-_R e^+_L \to f\bar{f}) = \Sigma_{RL}(1+\cos\theta)^2 + \Sigma_{RR}(1-\cos\theta)^2$$

*add term ~$\sin^2\theta$ in case of non-relativistic fermions e.g. top close to threshold



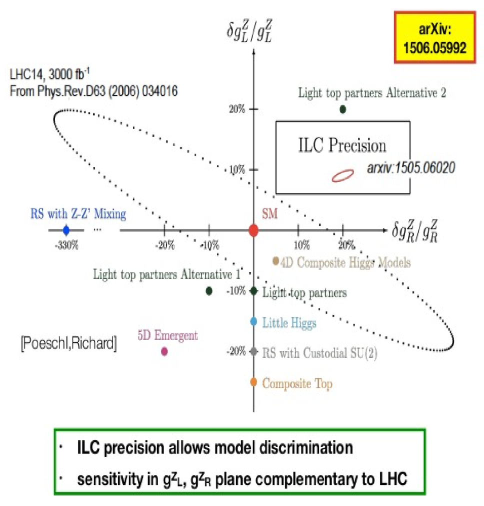


- **Linear colliders energy upgradability** is crucial to study the **ttH** toploogies

Σ_{ij} are helicity amplitudes that contain couplings g_L, g_R (or F_V, F_A)
$\Sigma_{ij} \neq \Sigma_{ij}'$ => (characteristic) asymmetries for each fermion
Forward-backward in angle, general left-right in cross section
All four helicity amplitudes for all fermions only available with polarised beams

Top-EW couplings and BSM

- Many **BSM scenarios** (i.e. Randall Sundrum, compositeness, Higgs unification models…) predict **heavy resonances coupling to the (t,b)** doublet and also lighter fermions (i.e. c/s quarks)
- **BSM** resonances tend to **couple to the right components.**



Sensitivity to huge variety of models with **compositeness and/or extra-dimensions** complementary to resonance searches

Also from other e⁺e⁻ -> ff:
- probe Z' up to ~10 TeV 500fb⁻¹ @ 500 GeV (initial run)
- up to ~17 TeV for 1ab⁻¹ at 1 TeV
- polarised beams gain ~ 2TeV in reach

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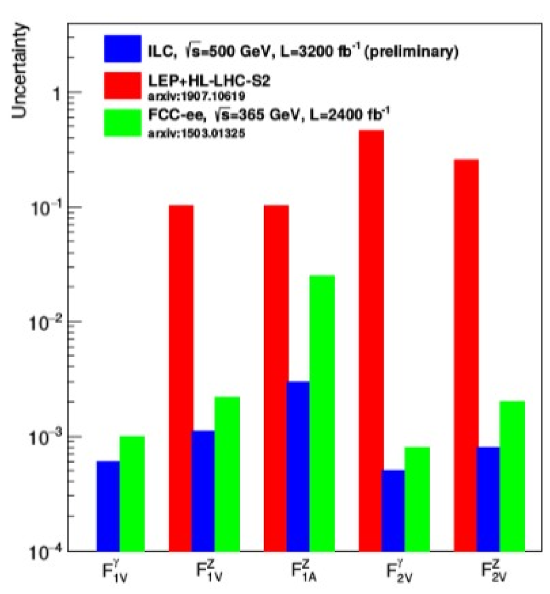

- e+e- collider way superior to LHC (√s = 14 TeV)
- Final state analysis at FCCee (polarisation)
  - Also possible at LC => Redundancy

- Two remarks:
  - 500 GeV is nicely away from QCD Matching regime
    Less systematic uncertainties
  - The determination of axial form factors highly benefit from higher energies

Mapping between FF and EFT Coefficients

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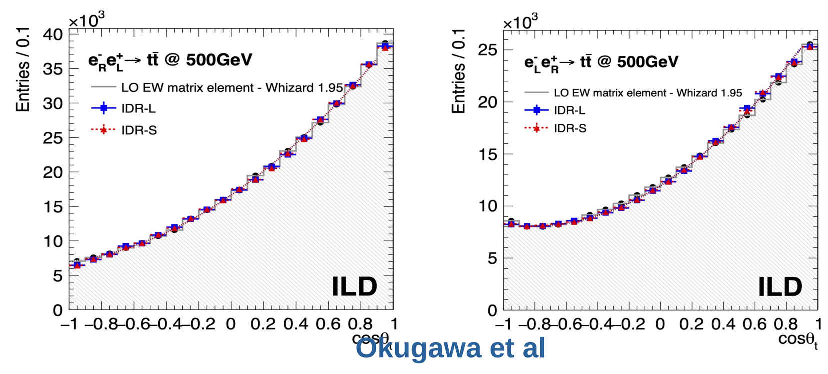
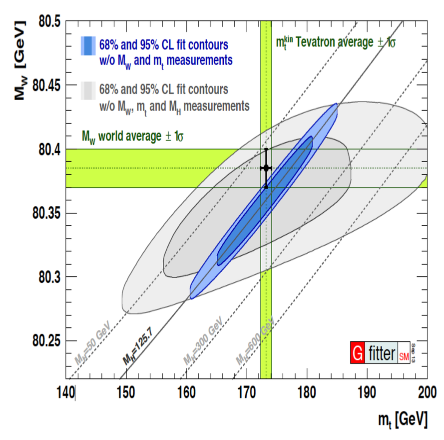


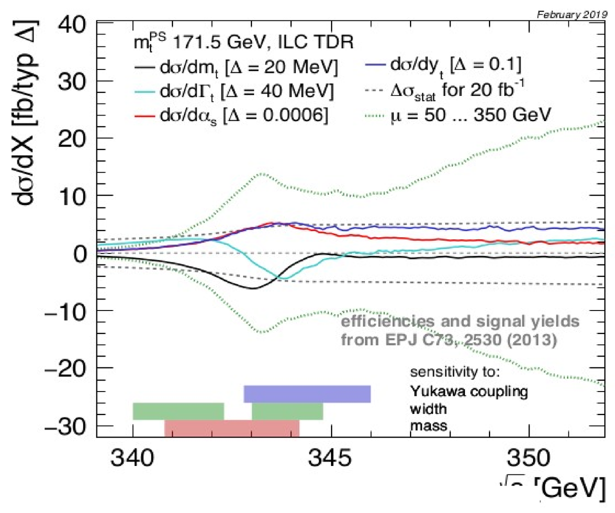
Full simulation studies

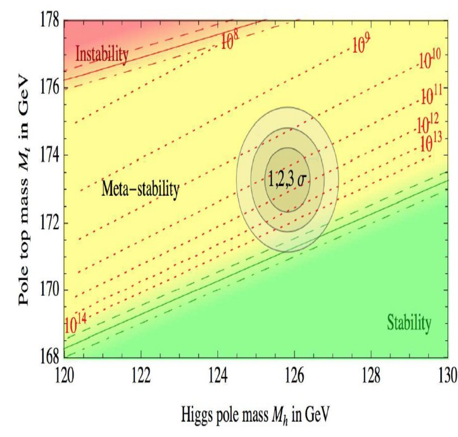
- Observables: **Forward backward asymmetries, angular cross section, etc**
- **Access to initial and final state polarization**

Top-quark mass

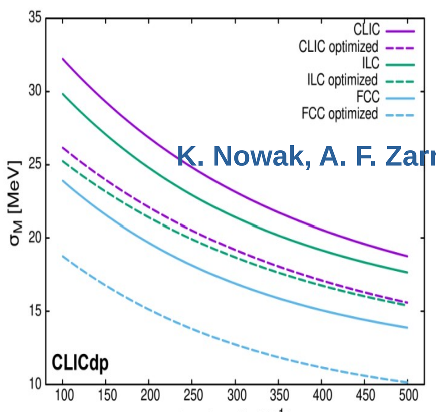


- **The top threshold provides excellent sensitivity to the mass and other top quark properties**
  - (more than) one order of magnitude better than HL-LHC
  - using **well-defined mass scheme**
  - **Sensitivity to : top-quark mass, width, yukawa coupling, strong coupling constant**

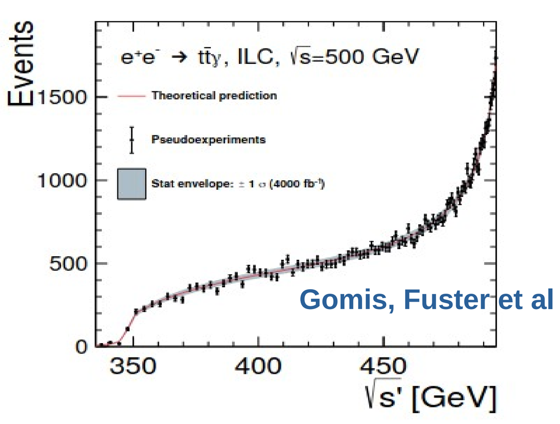




A key parameter in the SM.



Optimizing top-quark threshold scan at ILC using genetic alg.



Radiative return to threshold in e+e- → ttγ

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The ILC: report to Snowmass 2021 arxiv:2203.07622

First ECFA WORKSHOP.
on e⁺e⁻ Higgs / Electroweak / Top Factories
5-7 October 2022, DESY, Hamburg