# Top Mass at Electron-Positron Colliders

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MAX-PLANCK-INSTITUT
FÜR PHYSIK

# Top Mass Measurements in $e^+e^-$ Colliders

*Overview*

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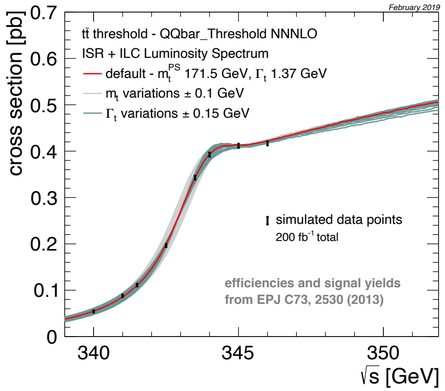
- The accelerator side: Requires sufficient collision energy for top pair production
  - So far thoroughly studied for ILC, CLIC, some derivative studies for FCCee

Three approaches to the top mass

The threshold scan around 350 GeV

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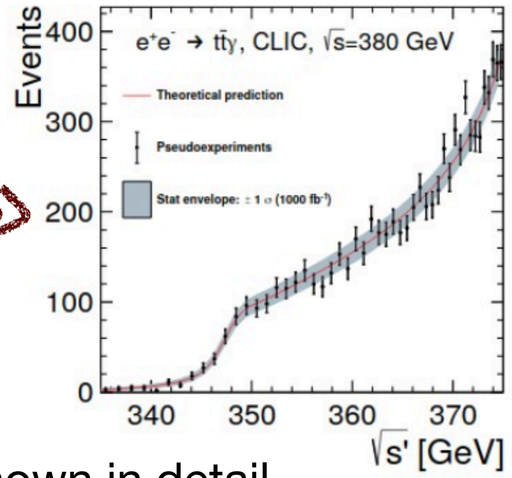
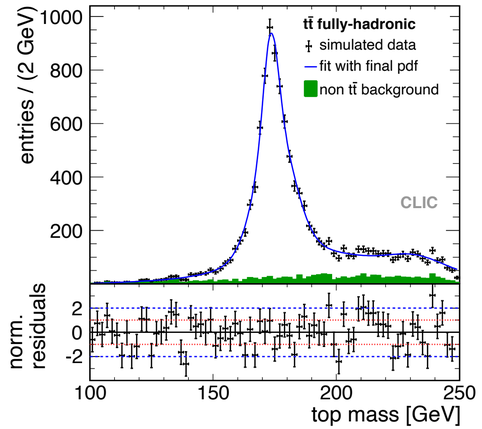



Direct kinematic reconstruction




not shown in detail, stat: ~ 20 - 40 MeV

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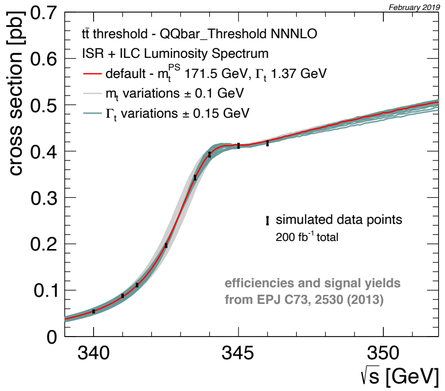


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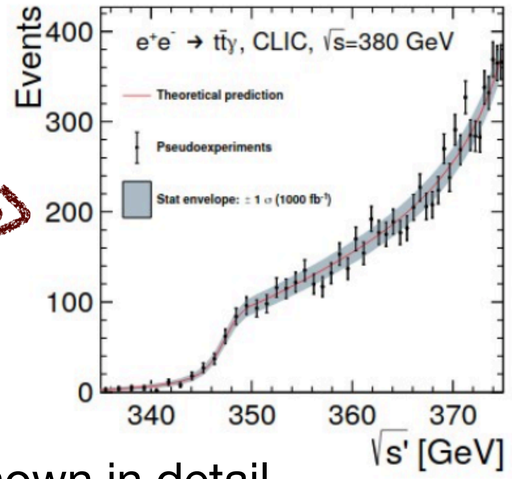


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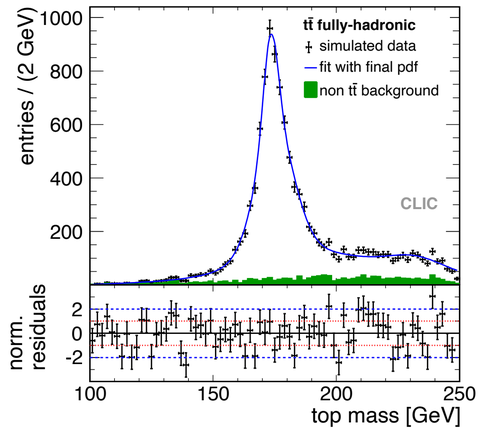


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*Key references:*

EPJ C73, 2530 (2013)
(CLIC, (ILC): Threshold, direct)

JHEP 11, 003 (2019)
(CLIC: Threshold, radiative, direct)

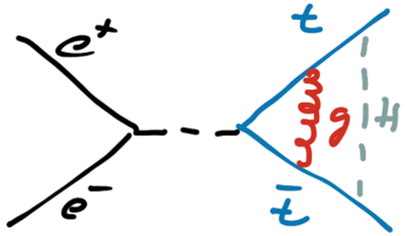
PLB 804,135353 (2020)
(ILC, CLIC: radiative)

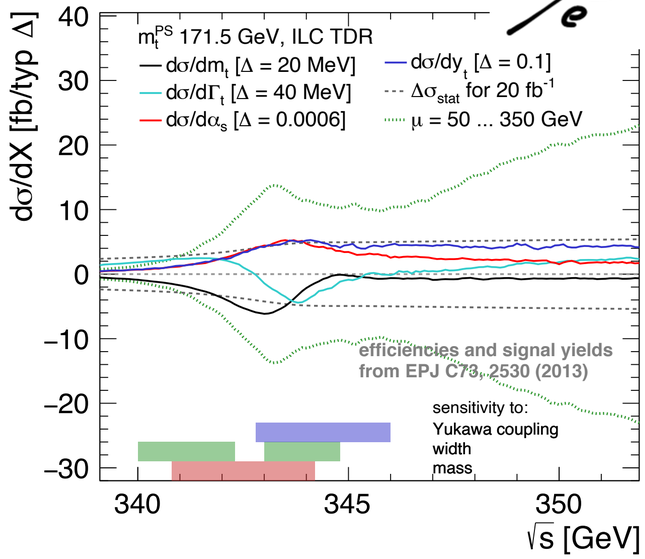
+ a rich set of reports and conference proceedings on arXiv

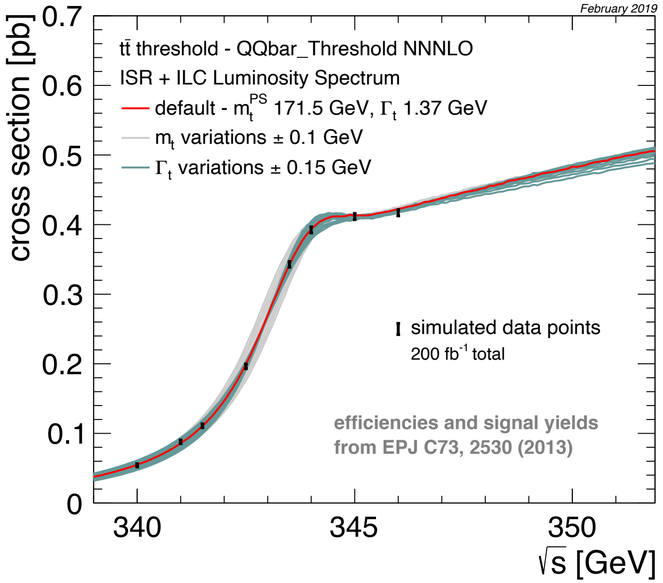
# Mass at the Threshold

*At CLIC, ILC, FCCee*

- The top threshold provides excellent sensitivity to the mass and other top quark properties
  - Measurement of the top quark mass in theoretically well-defined mass schemes




- Assuming an integrated luminosity of 200 fb$^{-1}$ (default for ILC, FCCee, x2 of CLIC standard scenario)
- Standard fit of mass only:
  ILC 12.2 MeV [stat]
  CLIC 13.3 MeV [stat]
  FCCee 10.4 MeV [stat]

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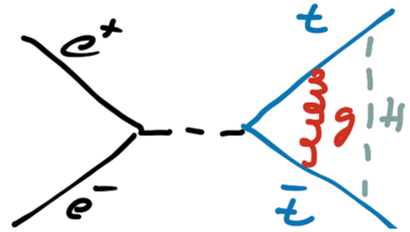


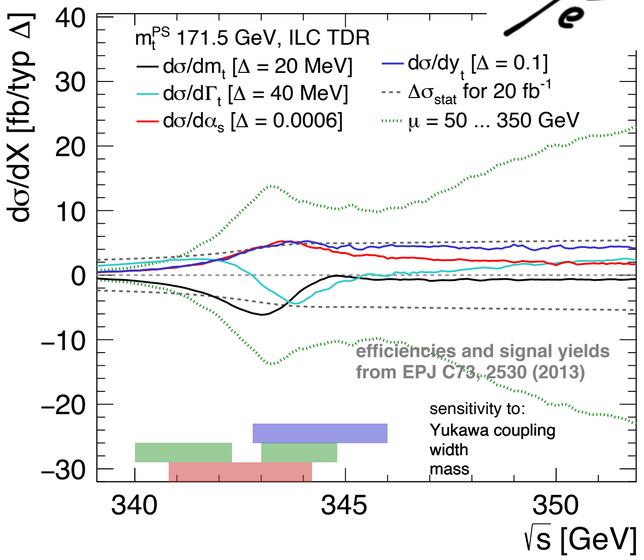


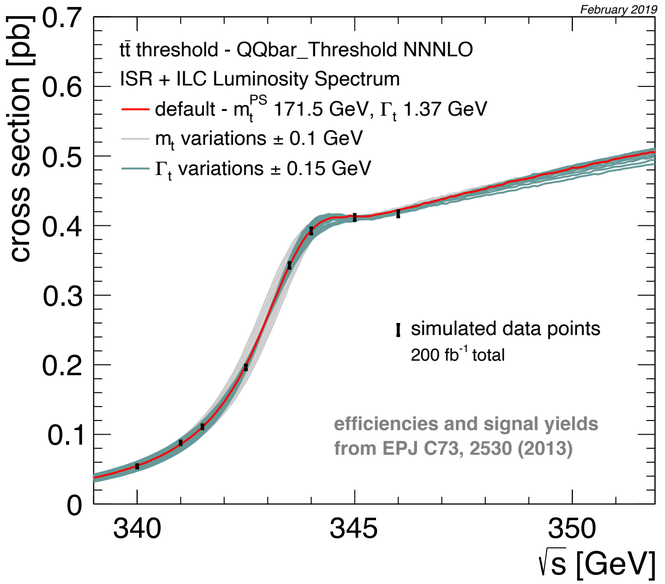


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| error source | $\Delta m_t^{\mathrm{PS}}$ [MeV] |
|---|---|
| stat. error (200 fb$^{-1}$) | 13 |
| theory (NNNLO scale variations, PS scheme) | 40 |
| parametric ($\alpha_s$, current WA) | 35 |
| non-resonant contributions (such as single top) | $< 40$ |
| residual background / selection efficiency | 10 – 20 |
| luminosity spectrum uncertainty | $< 10$ |
| beam energy uncertainty | $< 17$ |
| combined theory & parametric | 30 – 50 |
| combined experimental & backgrounds | 25 - 50 |
| total (stat. + syst.) | 40 – 75 |

- Detailed evaluation of systematic uncertainties
- Multi-parameter fits (mass, width, $\alpha_s$, $y_t$), scan optimization…

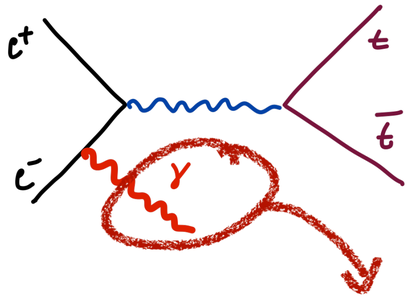


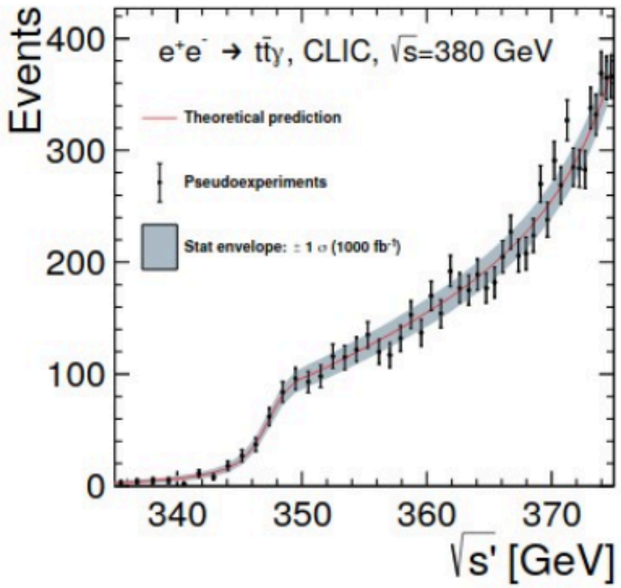
Frank Simon (fsimon@mpp.mpg.de)

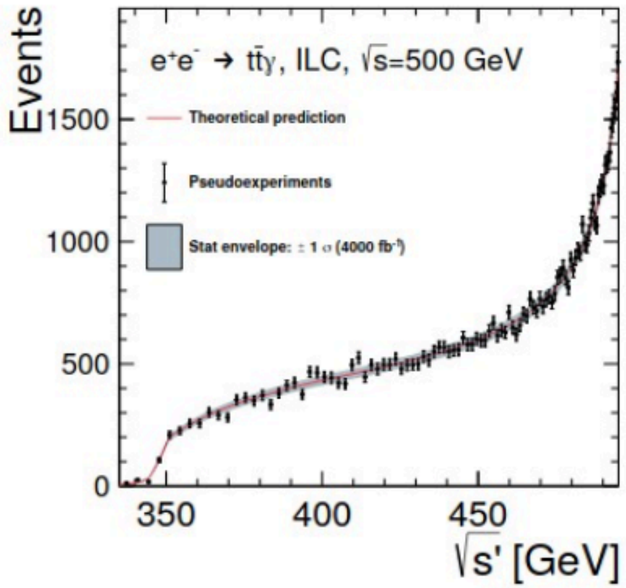
# Mass from Radiative Events

*At CLIC, ILC - 380 and 500 GeV*

- A new(er) idea to measure the top mass in a theoretically well-defined scheme in high-energy running above the threshold



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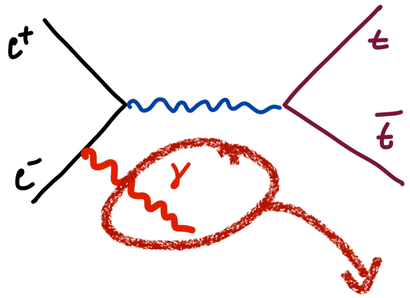
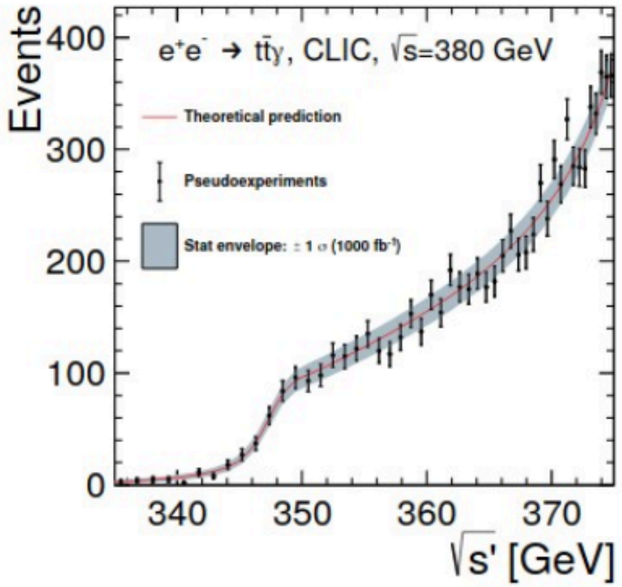
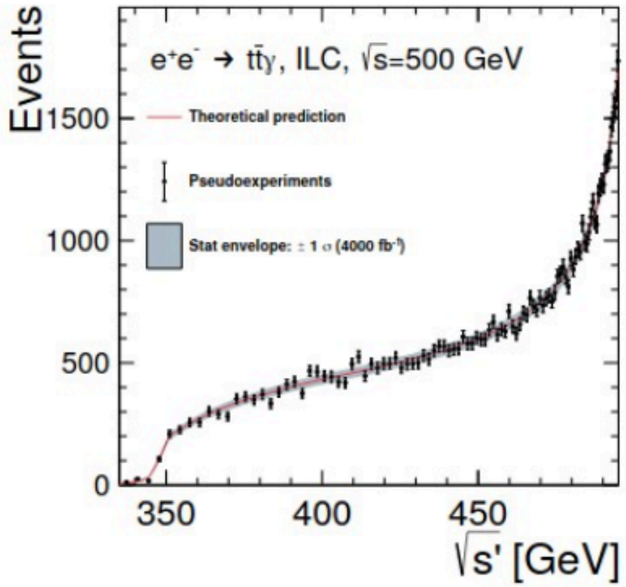



matched NNLO + NNLL calculation, luminosity spectrum folded in explicitly; Extraction of short distance MSR mass

| cms energy | CLIC, $\sqrt{s} = 380$ GeV | | ILC, $\sqrt{s} = 500$ GeV | |
|---|---|---|---|---|
| luminosity [fb$^{-1}$] | 500 | 1000 | 500 | 4000 |
| statistical | 140 MeV | 90 MeV | 350 MeV | 110 MeV |
| theory | 46 MeV | | 55 MeV | |
| lum. spectrum | 20 MeV | | 20 MeV | |
| photon response | 16 MeV | | 85 MeV | |
| total | 150 MeV | 110 MeV | 360 MeV | 150 MeV |



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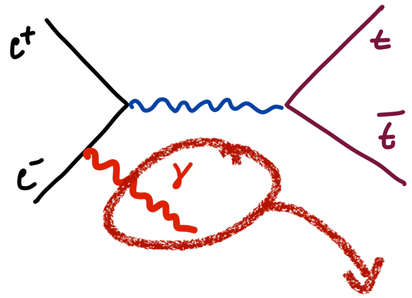


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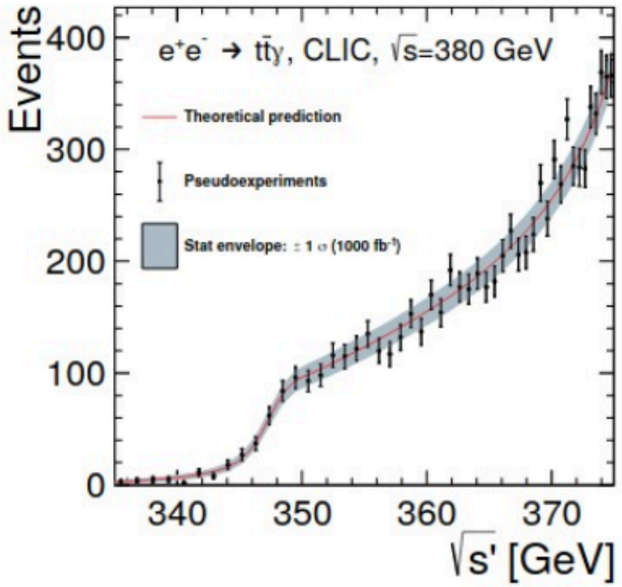
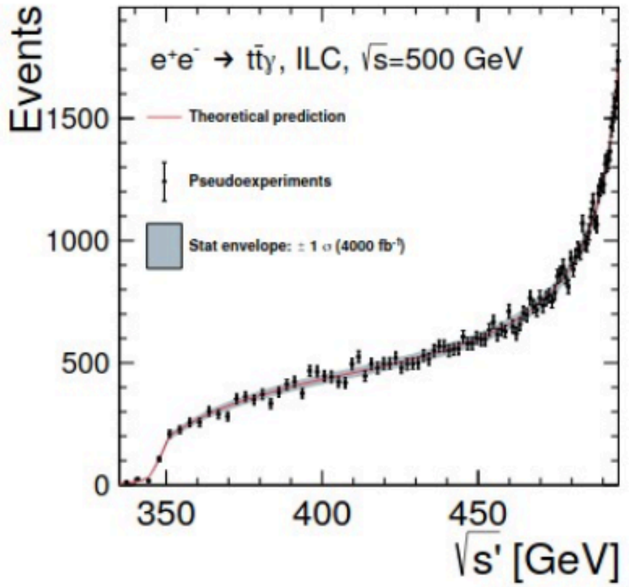
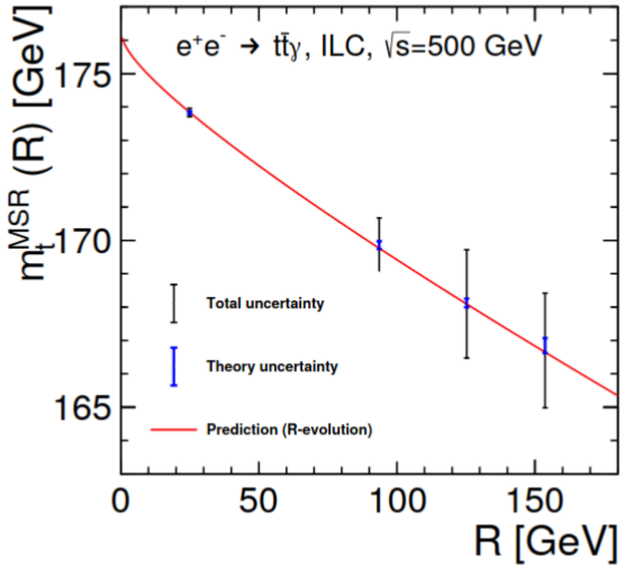



can provide 5σ evidence for scale evolution ("running") of the top quark MSR mass from ILC500 data alone



# Future Studies

*Ideas & Opportunities*

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- Threshold studies - standard total cross-section studies already very complete, personally planning an updated summary of results for CLIC, ILC, FCCee) - ideas beyond:
  - additional observables at the threshold: asymmetries (AFB, maybe also LR with polarisation), kinematic observables, … -
  - Study of the evolution of signal efficiency and background rejection in the threshold region with event generators - at the moment the studies use constant numbers
  - Unfolding with measured luminosity spectrum
- More generally
  - Explore possibilities to combine threshold and above-threshold measurements, possibly breaking degeneracies of $\alpha_s$, $y_t$
  - Further development of mass measurements in the continuum, connection to theory to establish the best precision in theoretically well-defined mass schemes
    - Includes systematics in kinematic reconstruction
  - Identify the best strategy to measure the top quark width (threshold, continuum)
- …

Many interesting possibilities!