# Towards a Top Threshold Event Generator

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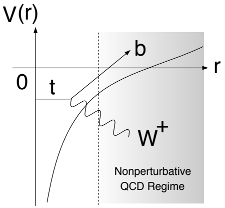
# Top Threshold at the ILC

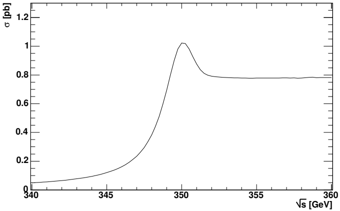
The top threshold at the ILC offers a unique QCD system to study :




- Large top quark mass allows precise perturbative QCD calculations of its properties.
- Large top width $\Gamma_t$ acts as infrared cutoff preventing hadronization effects.
- With main decay to $b\bar{b}W^+W^-$ top quark spin information is preserved in its decay products

- Can measure $M_t$, $\Gamma_t$ and $\alpha_s$ to high precision, together with measurements of the top-Yukawa coupling
- Clean lepton environment provides unprecetended precision potential

# Top Threshold and the Luminosity Spectrum




- The top will be measured at the ILC by a threshold scan at $\sqrt{s} \approx 2M_t$
- One of the main uncertainties in this measurement will come from knowledge of the machine's luminosity spectrum
- Various energy loss mechanisms give a complicated luminosity spectrum at the ILC

- Hence the top threshold observables will be smeared by the luminosity spectrum effects

$$\frac{d\sigma_{obs}^{e^+e^-}}{d\Omega}(\sqrt{s}) = \int_0^1 dx_1 dx_2 D_{e^+e^-}(x_1, x2, \sqrt{s}) \frac{d\sigma^{e^+e^-}}{d\Omega'}(x_1, x_2, \sqrt{s})$$

- For precise threshold physics, a good knowledge of the luminosity spectrum and its inclusion in event generation is fundamental

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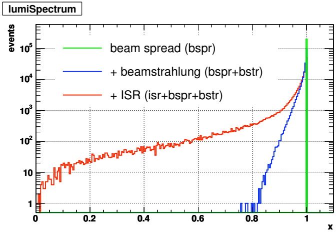


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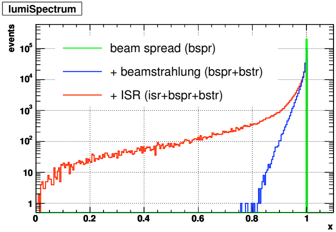


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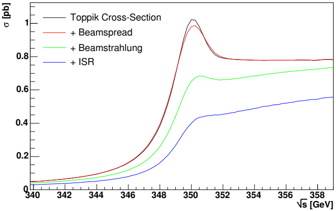


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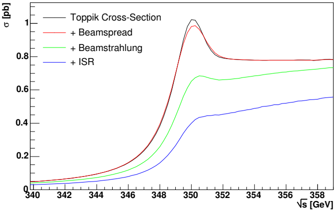


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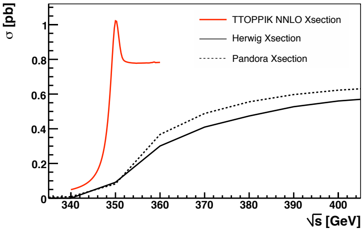
# Current Top Threshold Status




- Precision measurement depends on precise knowledge of threshold lineshape
- Current event generation tools fail to describe the top threshold
- Over the last 10-15 years, theoretical physicists have performed a wealth of precision calculations for top pair production at threshold.

- However, no event generator exists (yet) that uses these calculations so that precise physics studies can be performed
- The luminosity spectrum is an important factor in describing the top threshold, and thus a precise description must be incoporated in event generation

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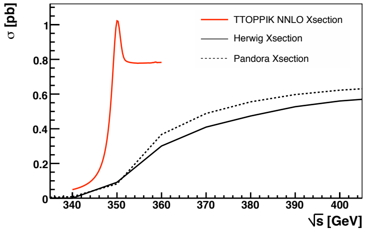


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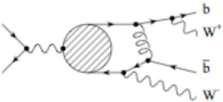
# topMC in a Nutshell

NLO rescattering corrections

Modify Green's functions

NNLL renormalization group improved total Cross section (only)

Scale total Cross section reduces theoretical uncertainty




NNLO Cross section + differential quantities $d\sigma/dp$ , $A_{FB}$ etc

Include Beam Effects !!

Top quark pair 4-momenta → Decay top quarks

Give decay products to Pythia / Herwig for further decays and hadronization

**Event Generator**

# Building blocks...

- NNLO QCD calculation by TOPPIK (A.Hoang & T.Teubner) and NNLL by Hoang, Manohar, Stewart, Teubner.
- Solving the Lippmann-Schwinger eq. numerically in momentum space using the Green function technique
- Green functions contain all the information of the QCD dynamics of the system
- Are related to observables by e.g.

$$\frac{d^3\sigma}{dp^3} = \frac{3\alpha_s^2\Gamma_t}{4\pi m_t^4}(1-P_+P_-)[(a_1+\chi a_2)(1-\frac{16\alpha_s}{3\pi})|G(p,E)|^2 + \\ +(a_3+\chi a_4)(1-\frac{12\alpha_s}{3\pi})\frac{p}{m_t}Re(G(p,E)F^*(p,E))cos\theta]$$

- Also possible to implement top polarization in MC framework (important for e.g. anomalous couplings)

# Fast Generator

- Main problem with TOPPIK is speed !!
  ($>$ 1.5sec per calculation)
- Forbids direct use in event generation
- Solution is fast access to the Green functions
- This is done by fast 4-dimensional interpolation on Green functions in $(M_t, \Gamma_t, \alpha_s, \sqrt{s})$ parameter space

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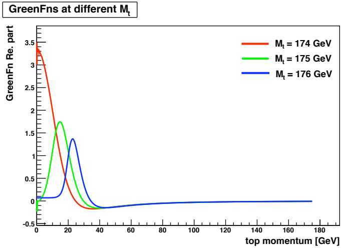


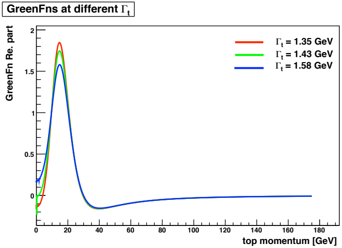

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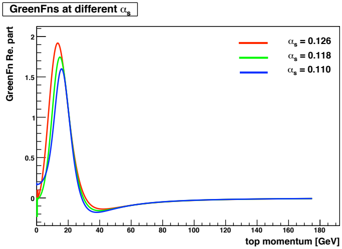


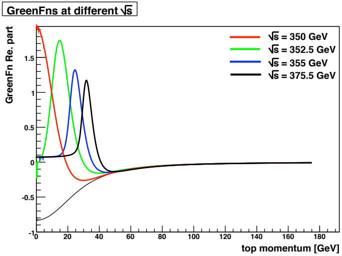

# Fast Multidimensional Interpolation

- Calculate with TOPPIK once and store interpolation grid in $(M_t, \Gamma_t, \alpha_s, \sqrt{s})$
- Perform fast piecewise linear interpolations in required parameters
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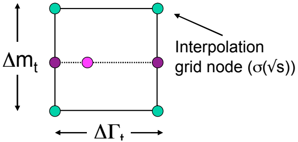

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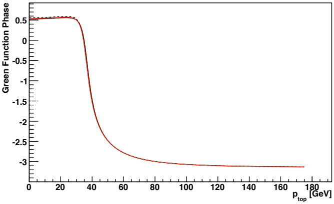


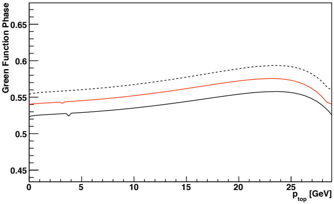

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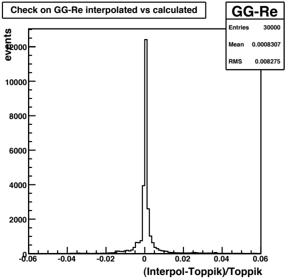


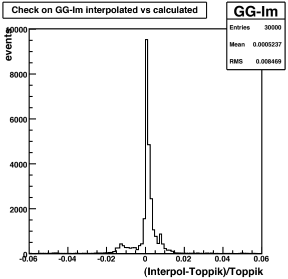

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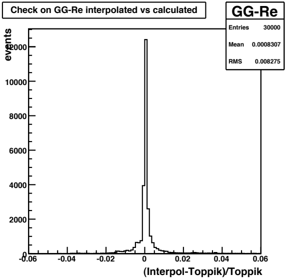


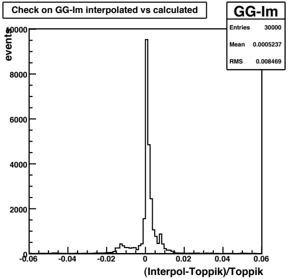

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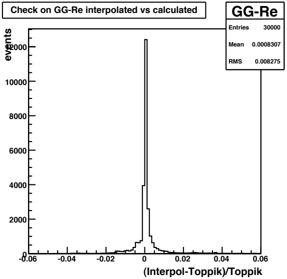


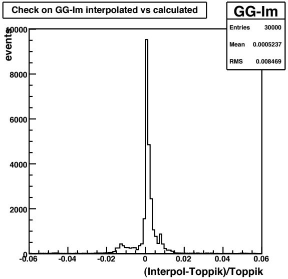

# Reproducing Calculations

- Implement full calculations in OO framework
- Reproduce Gauss-Legendre integration grid

$$\int f(x)dx \approx \sum_{i=1}^{n} w_i f(x_i)$$

- S-wave differential momentum distribution
- Total cross sections

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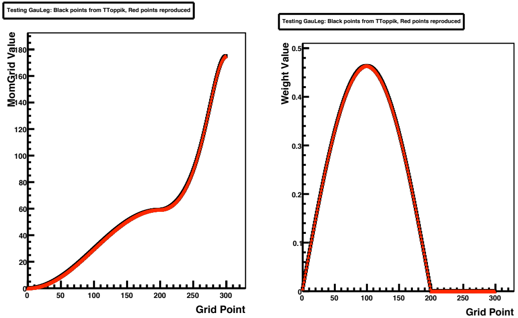

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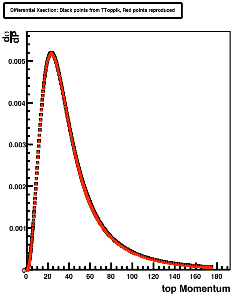


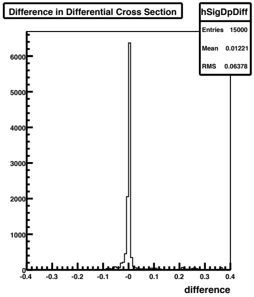

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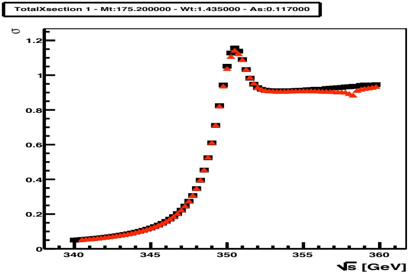

# Summary and the Future

- We are (almost) there...
- Major problem solved: Demonstrated that interpolation works !
- Can reproduce all 'observable' quantities implemented in TOPPIK
- Also straight forward to use different interpolation grids when new calculations become available ...
- Next step is to feed these quantities in a MC Integrator (Foam, Vegas) and start generating simple events
- Then decay the top quarks and interface to multipurpose generator for further decays and hadronization
- Start thinking about implementation of beam effects