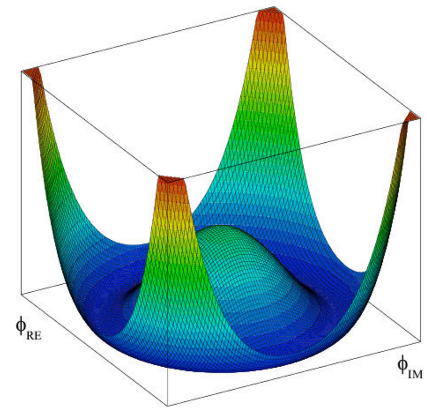
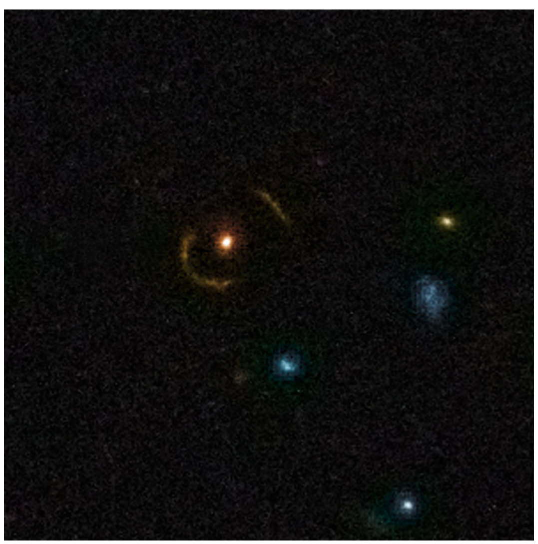
Theory activities for the LHC

Babis Anastasiou
ETH Zurich

LHC expectations

UNDERSTAND THE MECHANISM OF ELECTRO-WEAK SYMMETRY BREAKING





DISCOVER DARK PARTICLE (with some luck)

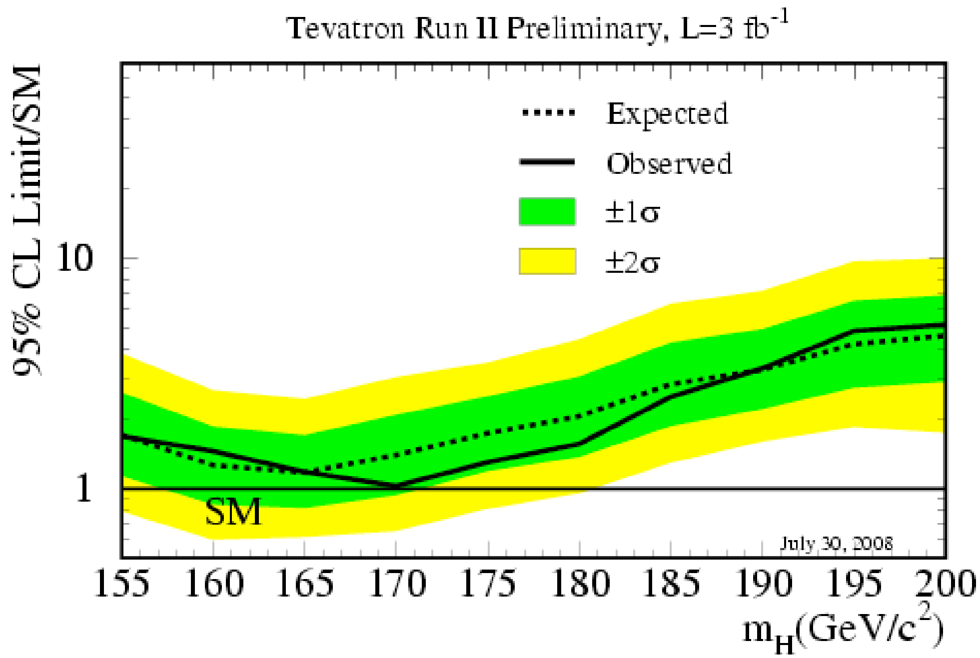
TEVATRON Higgs boson experience

Already, the Tevatron is becoming sensitive to mainly:

$$pp \to H \to WW \to ll\nu\nu$$

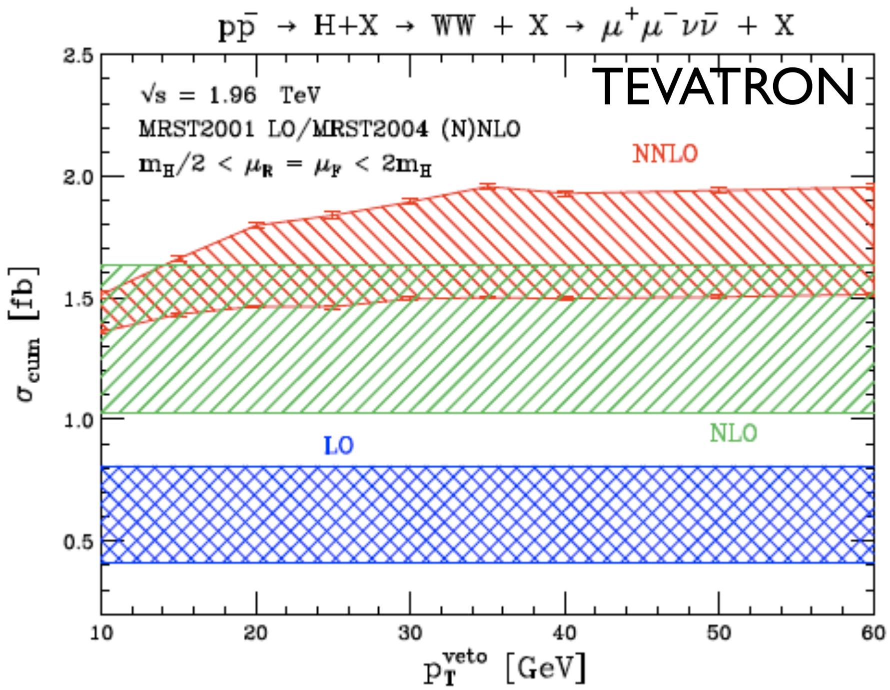
A channel which can yield a ~160 GeV Higgs boson discovery with little luminosity at the LHC

Dittmar,Dreiner;
Davatz, Dittmar, Giolo-Nicollerat



ICHEP 08, *Matt Herndon*

Cross-section with cuts



CA, Dissertori, Grazzini, Stoeckli, Webber

Veto on two-jets / cuts on missing transverse momentum / lepton invariant mass, pt, and rapidity

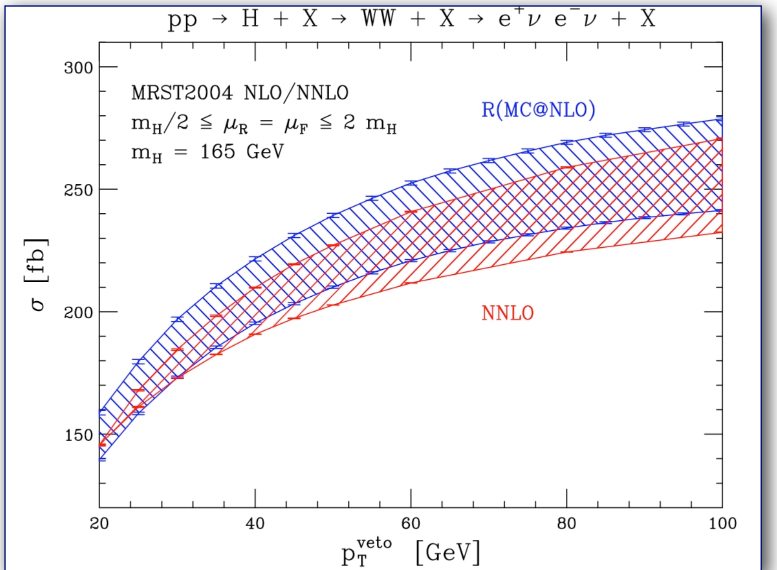
-Large K-factor for total cross-section

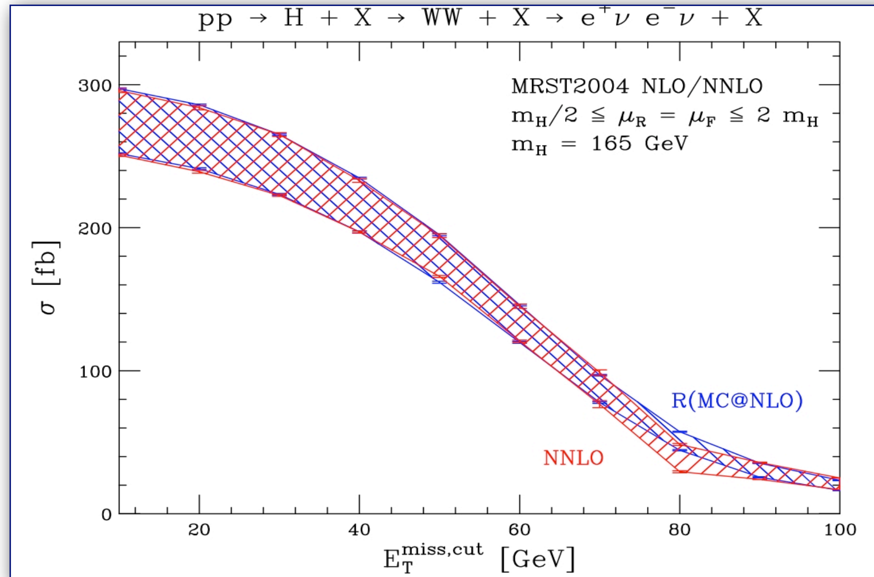
-Smaller K-factor for cross-section after cuts

Currently validating MC@NLO, HERWIG, vs NNLO for this process

How good are generators?

CA, Dissertori, Stoeckli, Webber





Generators (MC@NLO & HERWIG) agree very well with NNLO efficiencies

LHC:

We can approximate:

$$\sigma_{cuts} \approx \sigma_{cuts}^{nnlo} \approx \sigma_{cuts}^{generator} \times \frac{\sigma_{incl}^{nnlo}}{\sigma_{inc}^{generator}}$$

Higgs boson: a pseudo-Goldstone?

Hard to satisfy Electroweak Precision Tests and associate the Electroweak Symmetry Breaking with strong dynamics at Mw

Strong dynamics and an ``effective” Higgs boson is possible:

- Little Higgs
- Warped extra dimension

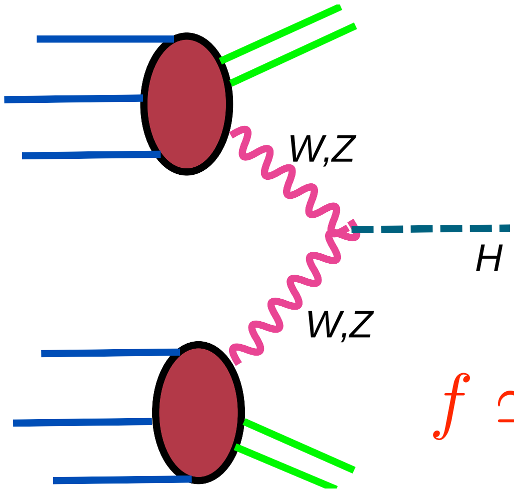
Common effective theory for Higgs and SM gauge boson/fermion interactions

Giudice, Grojean, Pomarol, Rattazzi

Strong dynamics at a (not so high) scale with a global symmetry.
This is broken spontaneously: Goldstone boson
A subgroup is gauged under SU(2) x U(1) + Yukawa interactions of SM and strong sector particles: massive (pseudo) Goldstone

Common phenomenology

Giudice, Grojean, Pomarol, Rattazzi



All couplings of the Higgs boson to other SM particles may be suppressed by a factor: $\sqrt{1-\frac{v^2}{f^2}}$

$$f \simeq 500\mathrm{GeV} \quad \sigma_{WBF} \approx 75\% \quad \sigma_{WBF}^{SM}$$

Increase with center of mass energy of WW scattering and Higgs pair production amplitudes:

$$\mathcal{A}\left(Z_L^0 Z_L^0 \to hh\right) = \mathcal{A}\left(W_L^+ W_L^- \to hh\right) = \frac{c_H s}{f^2}$$

Ongoing studies: Contino, Grojean, Moretti, Piccinini, Rattazzi

Model dependent pheno

Large global symmetry and symmetry breaking may vary but introduce new particles. E.g. a minimal SO(5)/SO(4) symmetry breaking pattern with custodial symmetry predicts top-partners with charge 5/3.

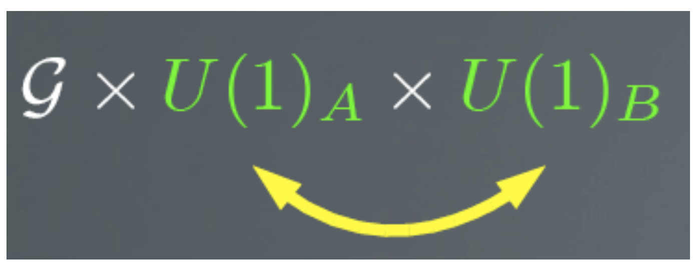
Models are compatible with electroweak precision data and B-physics constraints *Mark Gillioz* *ongoing: CA, Furlan, Santiago*

Complete verification will come with the LHC by observing such heavy quarks. Ongoing studies on single "Top" production. *Mrazek, Wulzer*

Dark matter in composite Higgs models

Panico, Ponton, Santiago, Serone

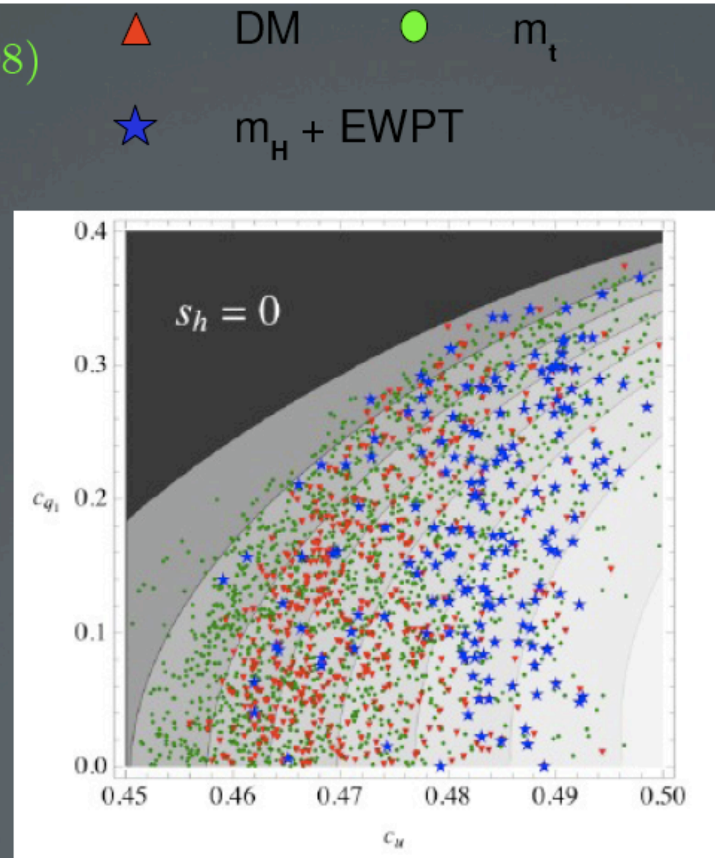
- Warped extra dimensions provide a calculable framework for Composite Higgs Models
- Dark Matter usually not present
- Can be included using a discrete exchange symmetry



Dark matter in composite Higgs models

Panico, Pontón, Santiago, Serone, PRD (08)

- *Realistic models with H as a composite pseudo Goldstone boson*
- *Correct EWSB, DM and EWPT in the same region of parameter space*



The SUSY paradigm

- It solves the hierarchy problem
- Gauge coupling unification
- Dark matter
- Rich but also very difficult phenomenology

Rich Higgs boson sector

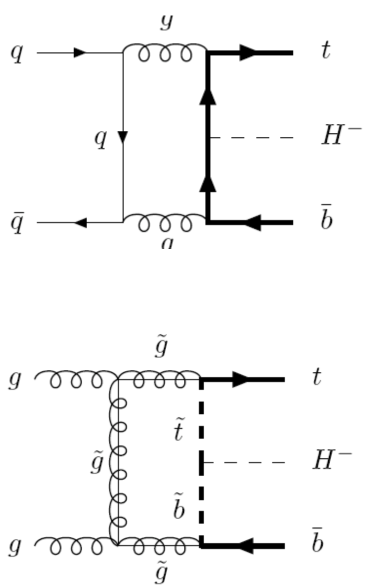
$$pp \to Q\bar{Q}'\phi$$

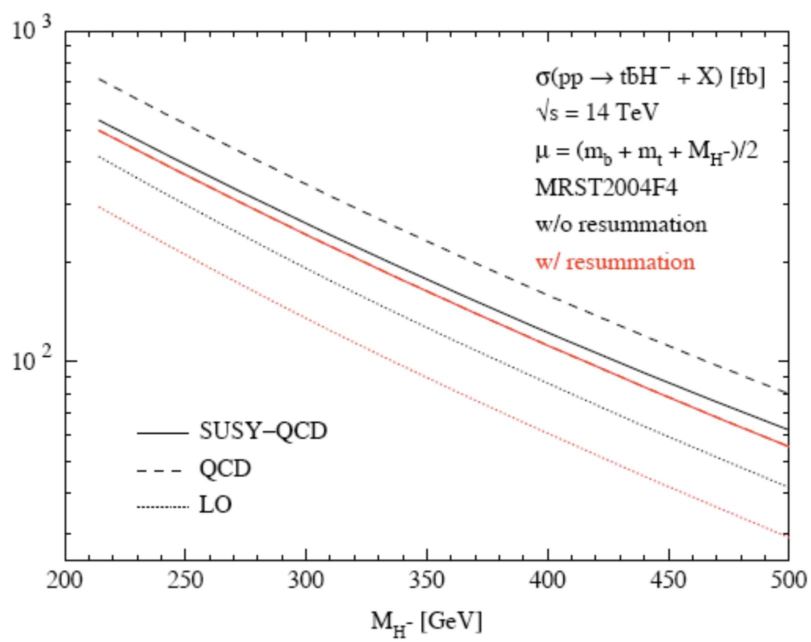
$Q = Q' = t, b \quad \phi = h, A, H$

$Q = t, \quad Q' = b \quad \phi = H^{\pm}$

QCD and SUSY QCD NLO corrections for associated production

Dittmaier, Haefliger, Spira, Kraemer, Walser



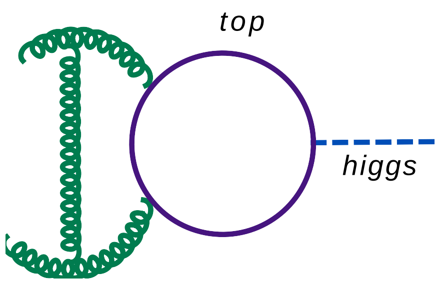


Both particles and sparticles in loops contribute

significantly

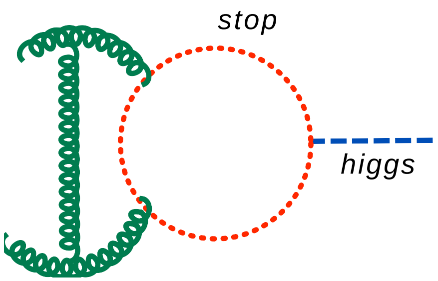
Calculations in SUSY are more challenging than in the SM

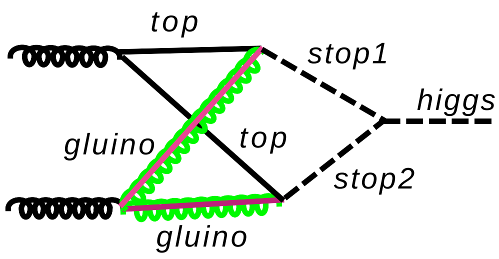
SUSY and gluon fusion



Spira, Djouadi, Graudez, Zerwas

CA, Beerli, Bucherer,Daleo, Kunszt
Aglieti,Bonciani,Degrassi,Vicini
Spira, Muhlleitner



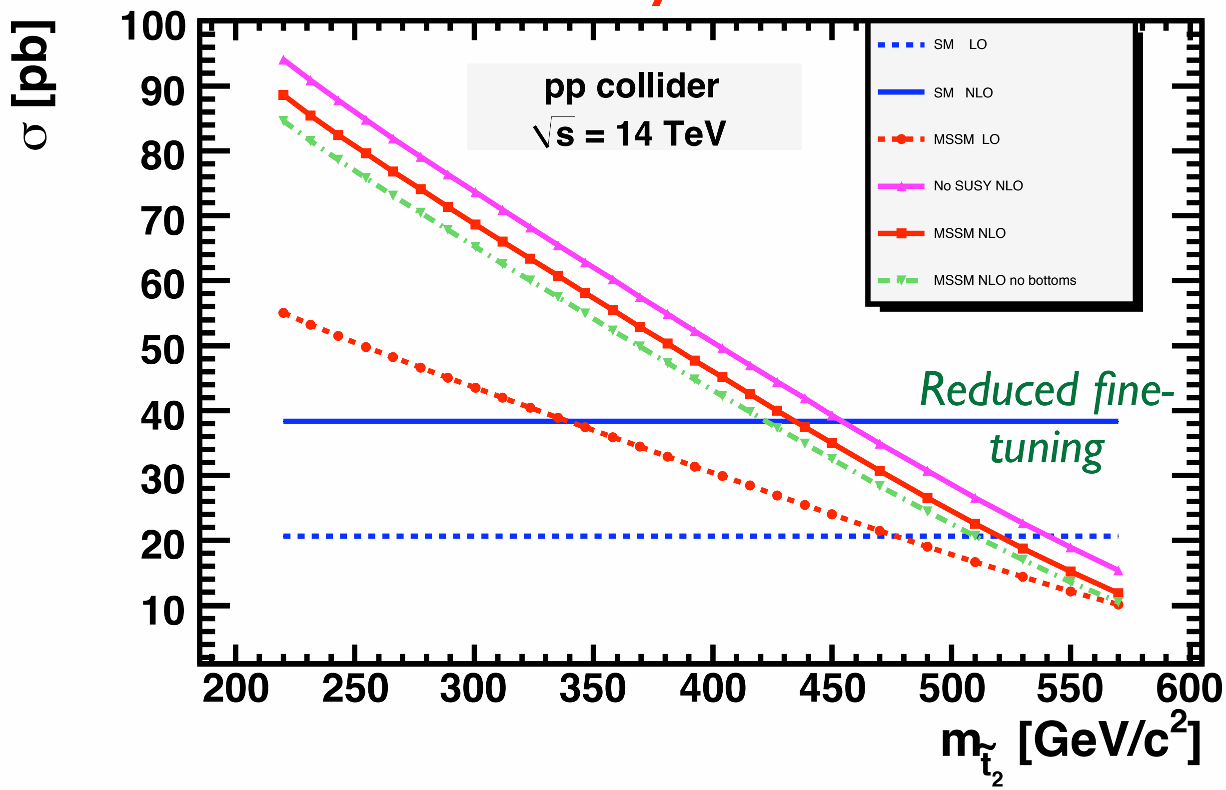


CA, Beerli, Daleo

New numerical method for multi-loop amplitudes

NLO higgs cross-section in the MSSM

Preliminary

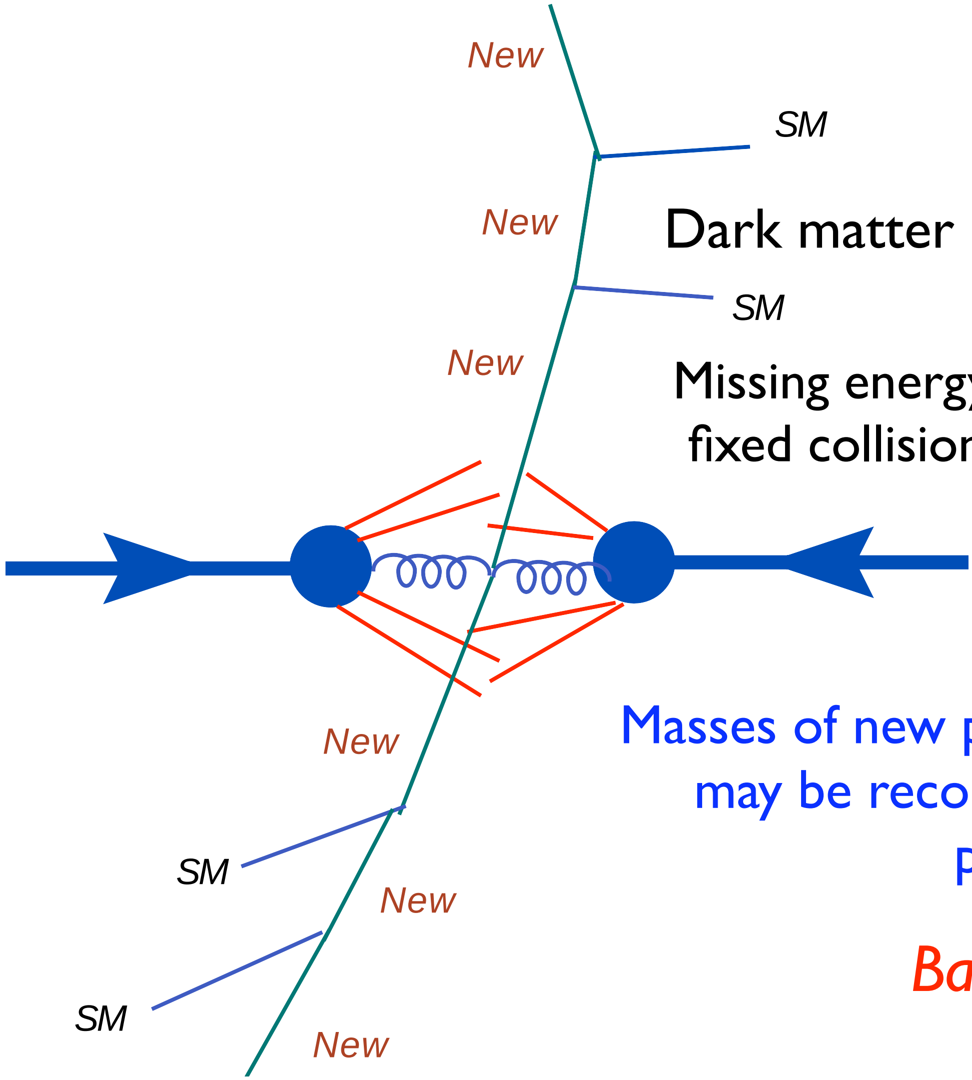


Cancelations needed to solve the hierarchy problem may reduce the gluon fusion cross-section

Low,Rattazzi

CA, Beerli, Bucherer, Daleo, Kunszt

Signals with dark matter candidates



Dark matter can be confused with neutrinos.

Missing energy measurement obscured by non-fixed collision energy and detector limitations

Masses of new particles and the dark particle may be reconstructible from “kinks” in pt-distributions

Barr, Gripaios,Lester

Dark backgrounds

$$pp \longrightarrow \nu\bar{\nu} + N\,\text{jets}$$

$p_t > 80\,\text{GeV}$, central $|\eta| < 2.5$ jets $\qquad \mu^2 = M_Z^2 + \sum_{jet} p_{t,jet}^2$

N	$\sigma(2\mu)[pb]$	$\sigma(\mu/2)[pb]$	variation
1	182	216	17%
2	47.1	75.4	46%
3	6.47	13.52	70%
4	0.90	2.48	93%

Alpgen

Large backgrounds

POOR leading order predictions

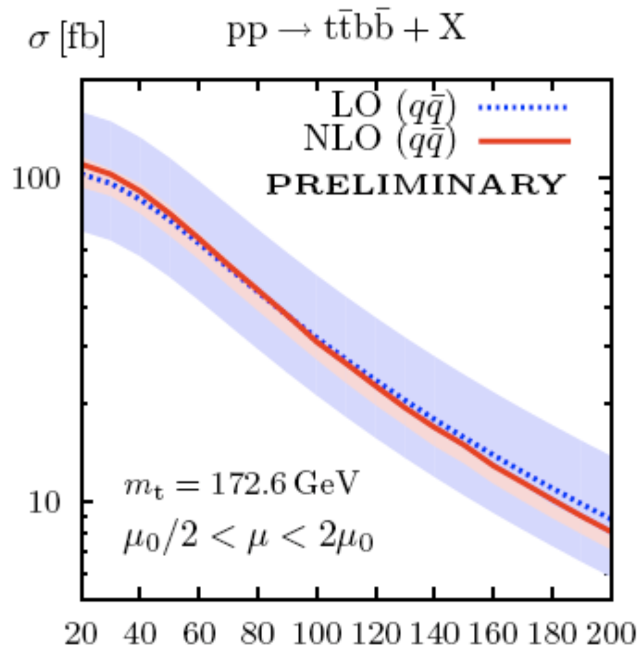
Limited TEVATRON experience

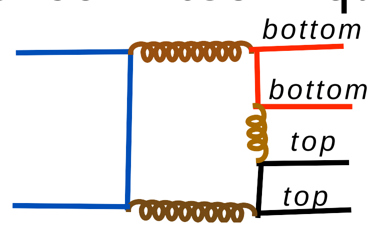
NEED for NLO cross-sections of multi-leg processes

Multileg processes @ NLO

$$\mathcal{M}_{1-loop} = \sum_{i=1}^{4} c_i(process) I_i(universal)$$

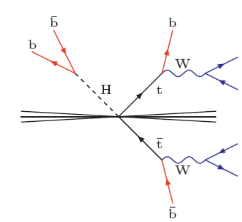
An impressive set of solid techniques by Denner, Dittmaier





State of the art computation

Important background to associated Higgs production



Ongoing work: gluonic channel

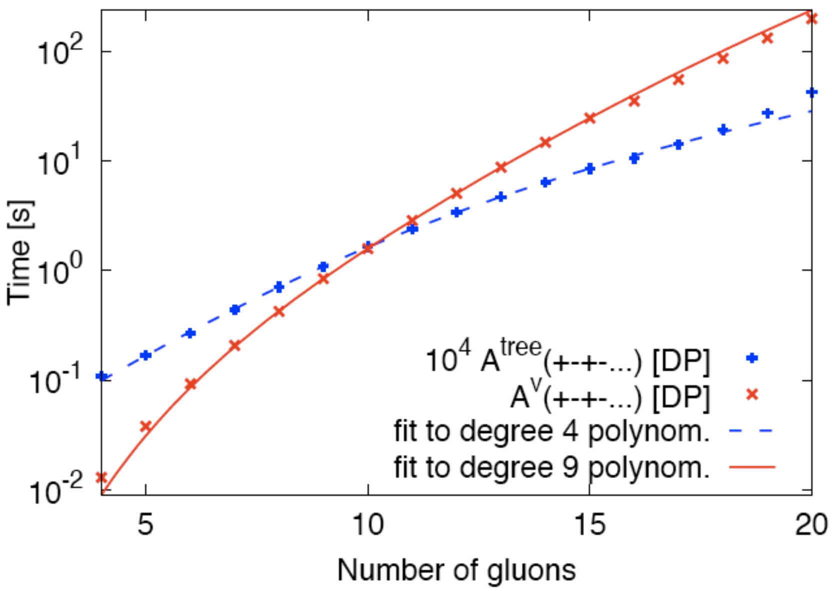
Bredenstein, Denner, Dittmaier, Pozzorini

New powerful NLO method

Ellis, Giele, Kunszt, Melnikov, Zanderighi

Loop amplitudes are a sum of residues corresponding to poles from on-shell particles in the loops

On the mass shell, loop amplitudes are in practice tree amplitudes. We should not need anything more than tree generators (e.g. ALPGEN) to compute them.



Test performance beyond our wildest dreams!!!

But do not forget the "basics"...

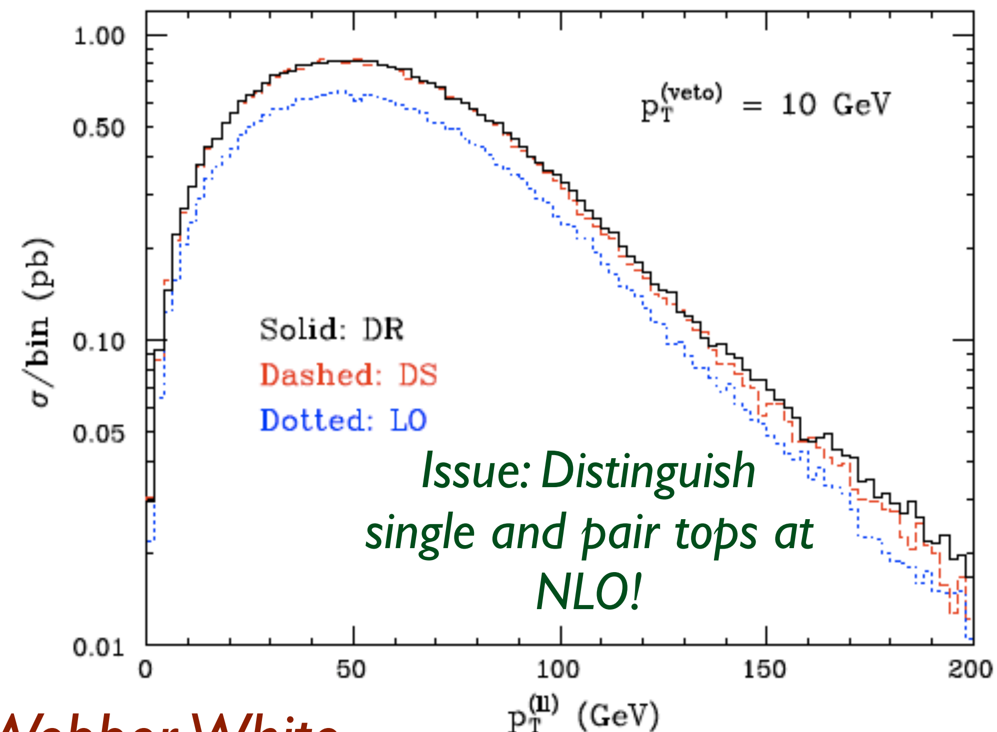
$pp \to WW$

$pp \to t\bar{t}$

$pp \to tW$

Tevatron gets only a glimpse of these processes....

Single top production is now simulated at NLO with matched parton-shower in MC@NLO



Issue: Distinguish single and pair tops at NLO!

Frixione, Laenen, Motylinski, Webber, White

Top-pair cross-section

Recent up to date study:

$$\sigma_{t\bar{t}}^{\rm NLO}({\rm LHC}, m_{\rm top} = 171{\rm GeV}) = 875^{+102(11.6\%)}_{-100(11.5\%)}({\rm scales})^{+30(3.4\%)}_{-29(3.3\%)}({\rm PDFs})\,{\rm pb}$$

Cacciari,Frixione,Mangano,Nason,Ridolfi

Negligible experimental statistical errors.

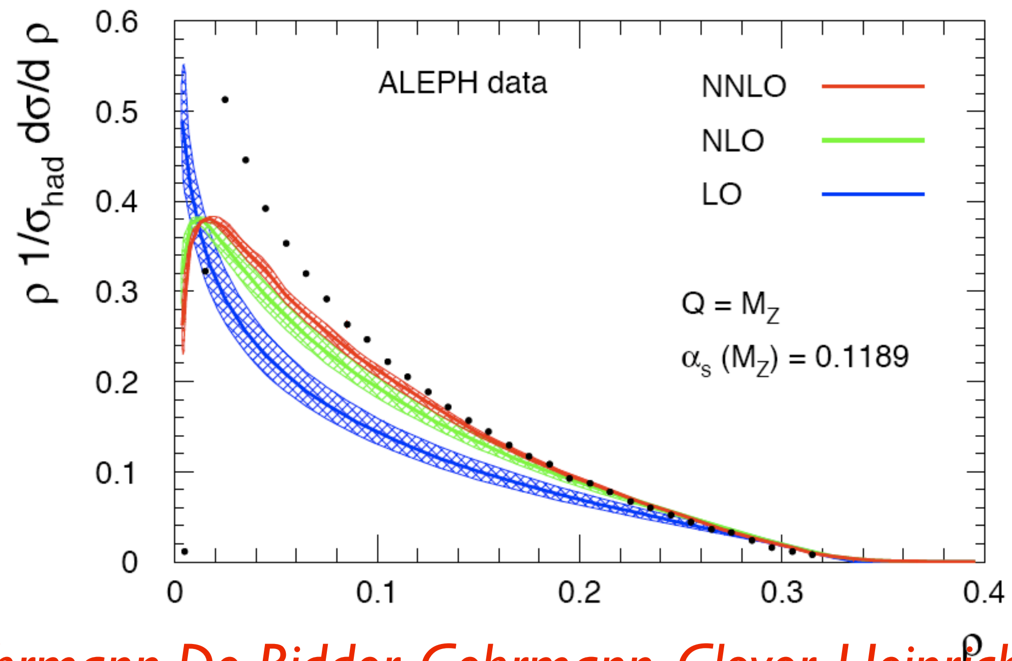
Early systematic errors of about 10%.
Will be reduced with larger luminosity

σ^{NNLO}???

NNLO experience

Heroic calculation of $e^+e^- \rightarrow 3jets$

Valuable accumulated knowledge of universal infrared radiation patterns at NNLO.

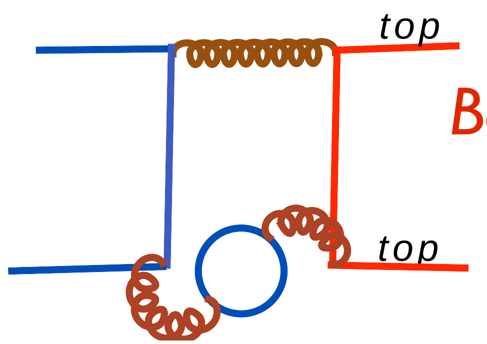


Gehrmann-De Ridder, Gehrmann, Glover, Heinrich

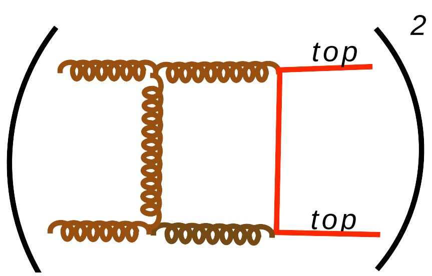
First determination of strong coupling with LEP data at NNLO

Dissertori, Gehrmann-De Ridder, Gehrmann, Glover, Heinrich, Henzel

Top cross-section @NNLO: first steps



Bonciani, Ferroglia, Gehrmann, Maitre, Studerus



CA, Aybat

"A long journey to ITHAKA"

Very important research I could not review

- Electroweak corrections for LHC processes *(Denner, Jantzen, Pozzorini; Muck; ...)*
- Theory developments on supersymmetry breaking *(Rattazzi, Kim, ...)*
- Minimal flavor violation in supersymmetry and RGEs *(Colangelo, Nikolidakis, Smith)*
- On UV completion of composite Higgs models *(Gripaios)*
- On neutrino physics and the LHC *(Shaposhnikov)*
- *...???*

Conclusions

- A very active Swiss particle theory community with LHC physics being a very top priority.
- Very strong in model building and precision computations.
- Keep us motivated....with good discussions and data!