

SPECTRUM

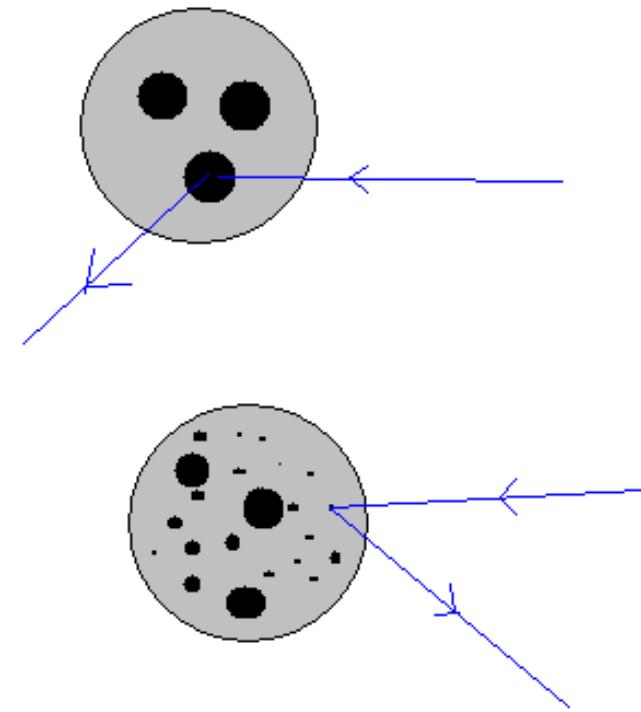
CERN – ATLAS Research Semester: Fall ‘14

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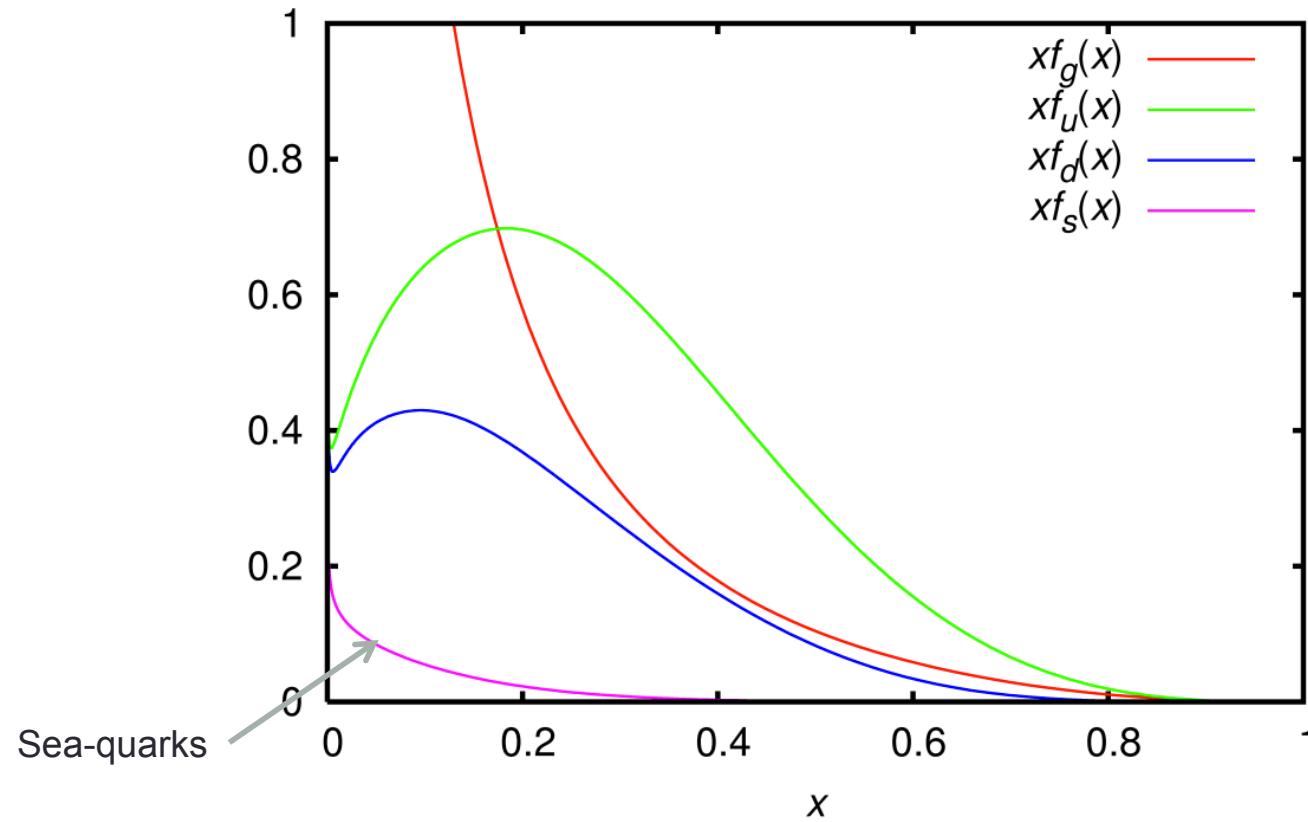
Proton Model

- Simple picture of proton:
 - Proton consists of 3 valence quarks (UUD)
- Proton really has more complex structure: Gluon interacting with quarks can emit quark-antiquark pairs (sea-quarks)
- Higher momentum scale (Q^2) , the more you ‘look’ inside the proton
- Different momentum scales result in different PDFs (high energies = more scattering due to sea-quarks)



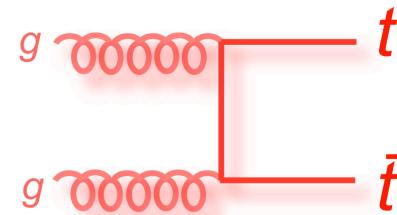
Parton Density Function

Defined as: probability density for finding a particle with a certain longitudinal momentum fraction x at resolution scale Q^2



Cross Section for Specific Process

$$g + g \rightarrow t + \bar{t}$$



Cross section

$$\sigma = \sum \alpha_s(\mu_R^2) \int f(x_1, x_2, \mu_F^2) M(x_1, x_2, \mu_R^2, \mu_F^2) dx_1 dx_2$$

Factorization scale

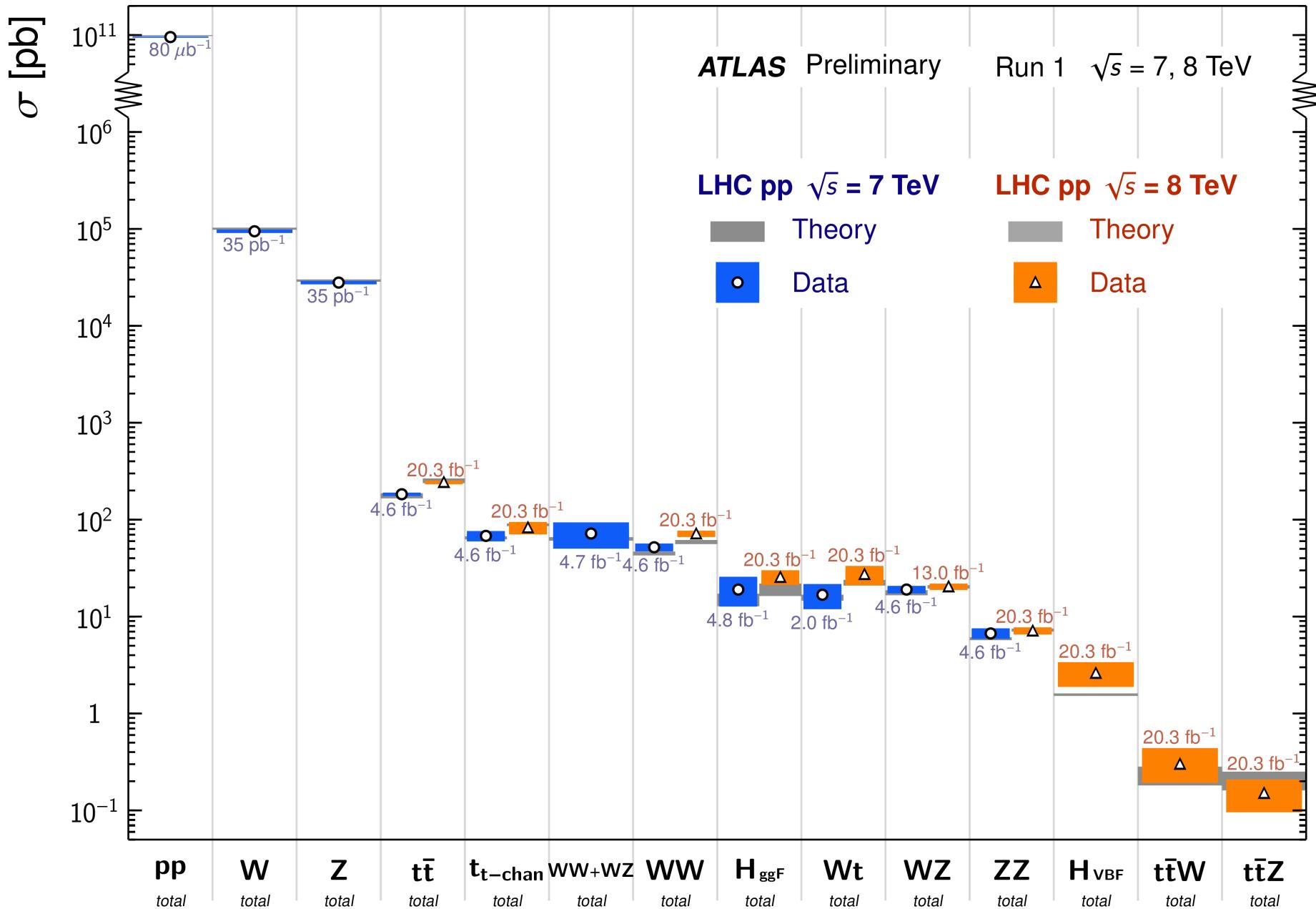
Renormalization scale

PDF
Obtained by
comparing experimental
cross section to calculations

Matrix element:
Calculated with
Feynman rules for
specific process

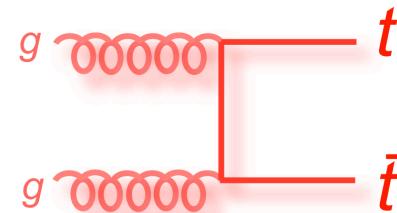
Standard Model Total Production Cross Section Measurements

Status: July 2014



Cross Section for Specific Process

$$g + g \rightarrow t + \bar{t}$$



Cross section

Factorization scale

Renormalization scale

$$\sigma = \sum \alpha_s(\mu_R^2) \int f(x_1, x_2, \mu_F^2) M(x_1, x_2, \mu_R^2, \mu_F^2) dx_1 dx_2$$

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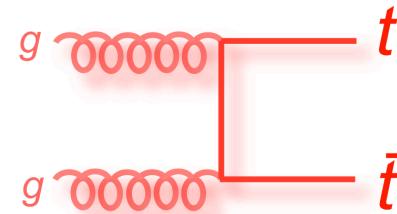
Matrix element:
Calculated with
Feynman rules for
specific process

Traditional NLO Programs

- Calculate cross section for specific processes
 - MCFM
 - NLOJet++
- Can take days or even weeks to perform calculation

Cross Section for Specific Process

$$g + g \rightarrow t + \bar{t}$$



Cross section

Factorization scale

Renormalization scale

$$\sigma = \sum \alpha_s(\mu_R^2) \int f(x_1, x_2, \mu_F^2) M(x_1, x_2, \mu_R^2, \mu_F^2) dx_1 dx_2$$

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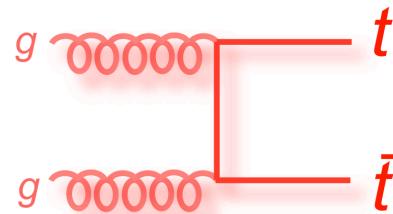
APPLgrid

- Performs the convolution of the PDF and the matrix element to quickly calculate the cross section
- Matrix elements are computed with NLO programs and stored in lookup tables
- PDFs are taken from LHAPDF Fortran/C++ library
- Allows fast access to PDFs and scale uncertainties
- Can be used in PDF fitting

Spectrum

- Facilitates plotting of data and theory predictions obtained from convolution of ME and PDF using ROOT
- Collect data tables and lookup tables (APPLgrid)
- Make them accessible to HEP community
 - Web server/GUI
- Interfaces with ROOT, APPLgrid, LHAPDF, others
- Multiple data formats from multiple experiments
- Re-design of existing program: *MyAnalysis*
- ~30kloc

2 PDFs, Markers



$$M_{t\bar{t}}$$

Invariant mass of
Top-AntiTop System

$$p = \langle E, p \rangle, p = \langle p_x, p_y, p_z \rangle$$

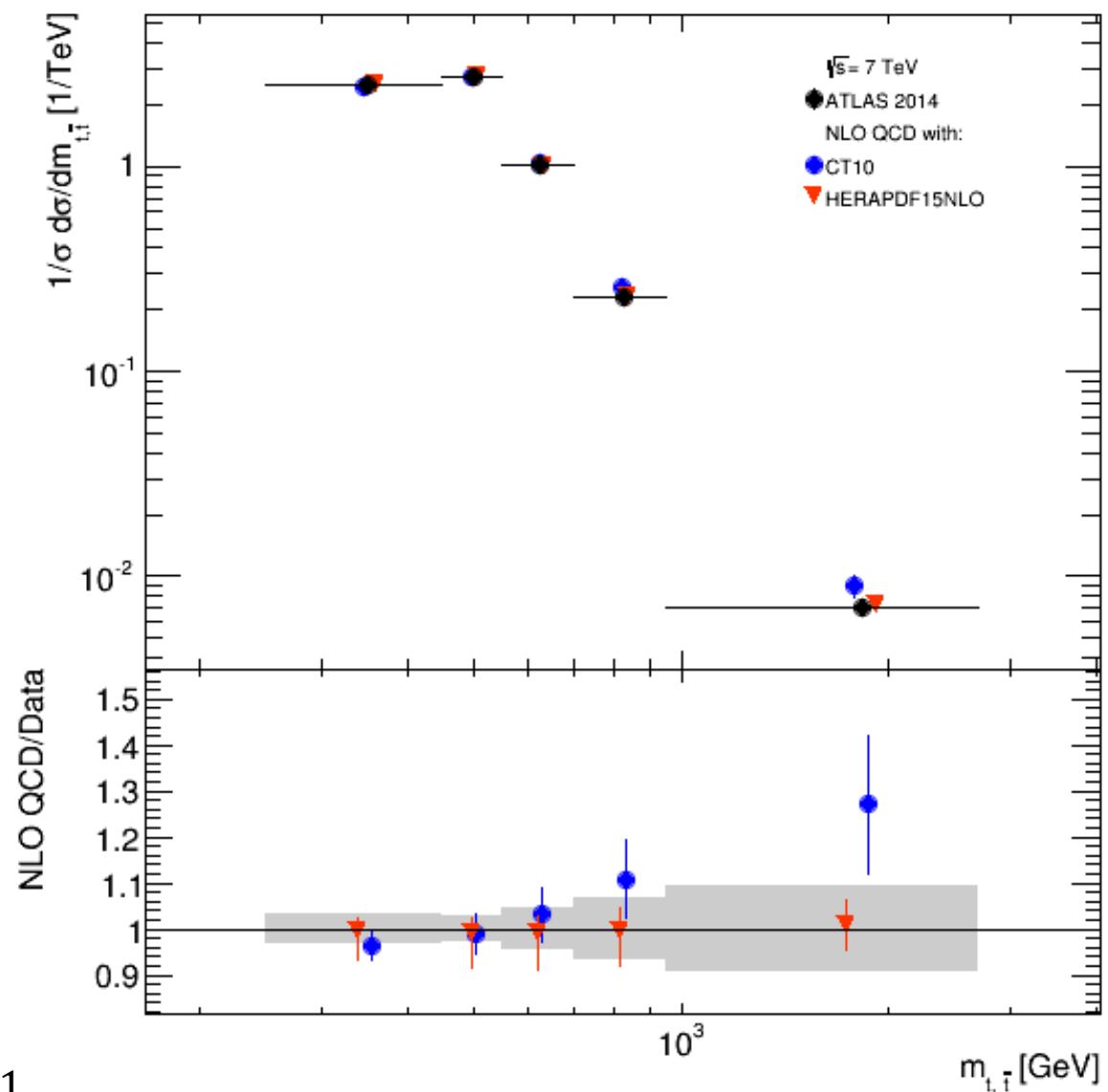
$$M^2 = p^2 = \sqrt{E^2 - p^2}$$

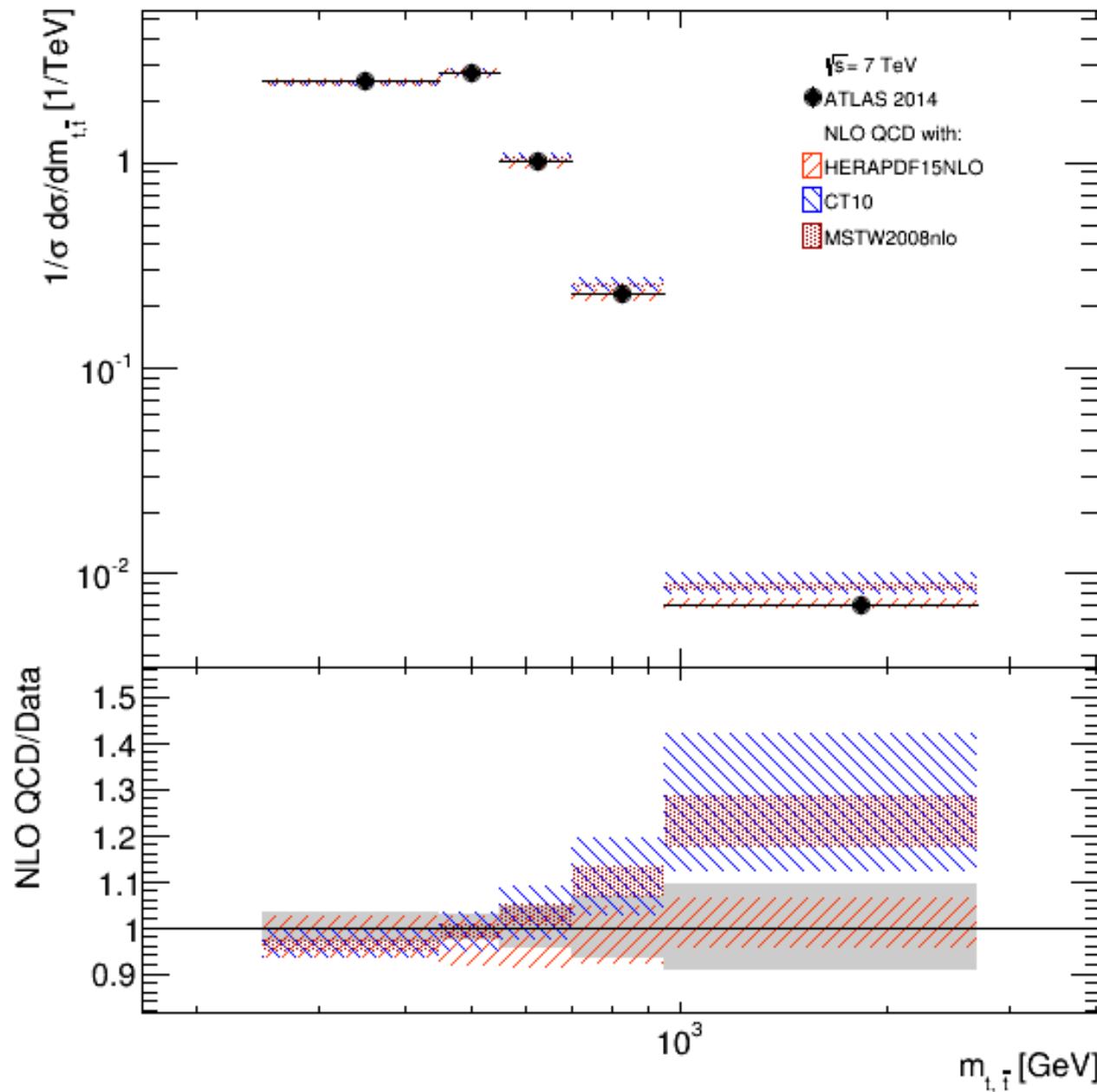
$$M_{t\bar{t}}^2 = (p_t + p_{\bar{t}})^2$$

An aside:

$$M^2 = p^2 = E^2, \quad p \Rightarrow 0$$

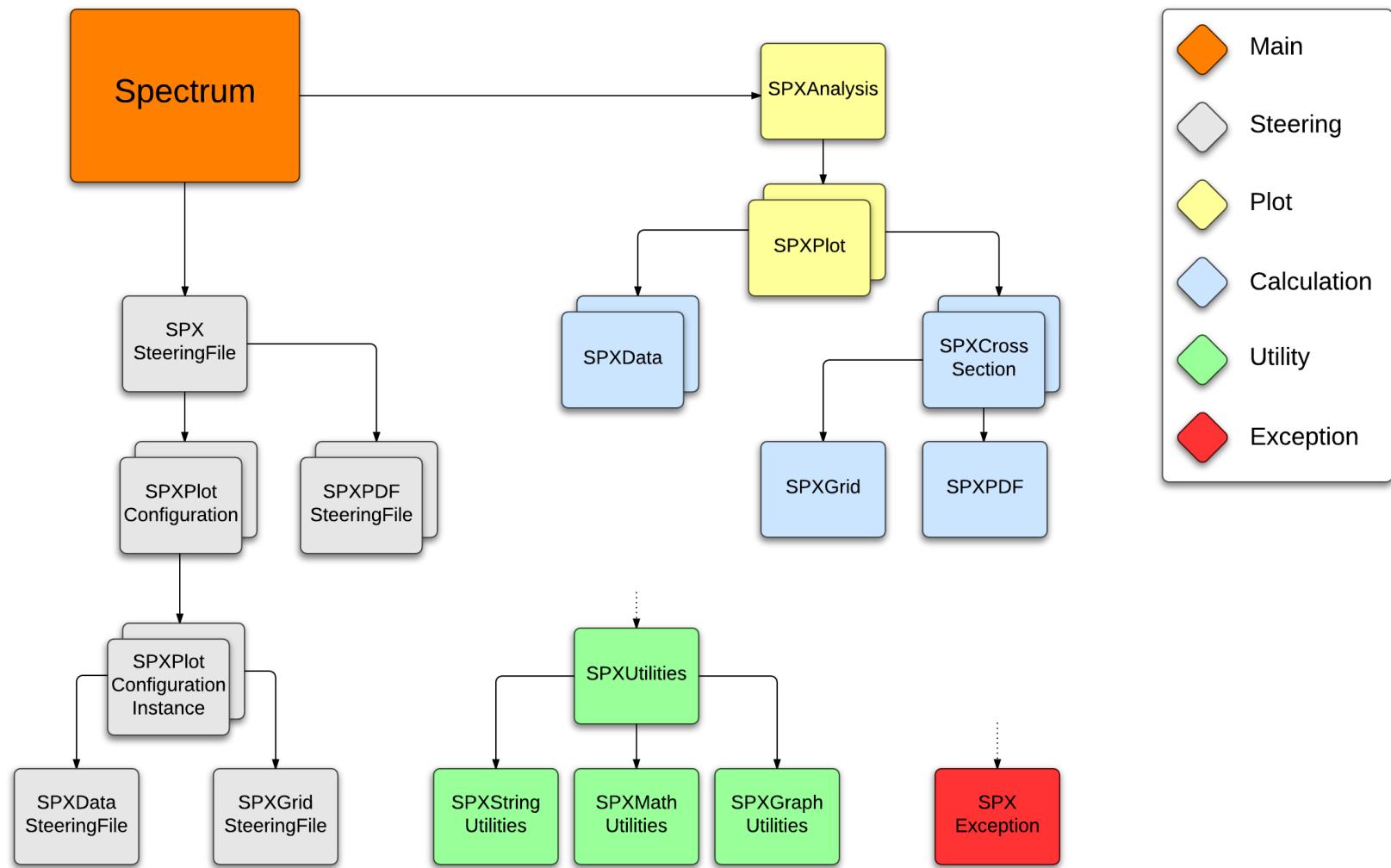
$$M = E \Leftrightarrow E = mc^2, \quad c = 1$$





Experimental Data

- Data formats
 - Spectrum T1S
 - Spectrum T1A
 - Spectrum T2S
 - Spectrum T2A
 - HERAFitter
- Systematic Errors
 - Symmetric or Asymmetric (S/A)
 - Total or Total + Individual (T1/T2)
 - Explicit (HERAFitter)



Steering File

- Inefficient parse methods
- Standardizing syntax
 - Capitalization, spelling
 - Old options, new options, supported options



- INI Reader Library (<https://code.google.com/p/inih/>)
 - INI: standard configuration file format

```
[Section Label]
    data = value
```
 - Accessed as:

```
data = reader->Get("Section Label", "data", "default
    value");
```

Old Steering File

```
vardesc atlas_mtt_5fb
reflinecolor 4
leglabel atlas-reference
%mcscalex 1000
%mcscalex 0.001
frameid 0
divideid 0
%
dataname MyData/top/cms2012_top_mtt_ljet-SCALED-T0-ATLAS.txt
gridname MyGrids/top/mcfm/topq-2012-08/nominal/grid--TTbar_mttcms.txt
markerstyledata 24
markercolordata 1
vardesc atlas_mtt_5fb
reflinecolor 2
leglabel cms-reference
reflinestyle 2
%mcscalex 1000
%scaley 1000.
frameid 0
%divideid 0
%
%dataname MyData/datanew/atlas2012_5fb_top_ptt_ljet.txt
%gridname grid--TTbar_pttlatlas5fb.root
%markerstyle 20
%markercolor 1
%frameid 0
%mcscalex 1000
%mcscalex 0.001
%divideid 1
%
%dataname MyData/datapub/top/cms2012_top_ptt_ljet.txt
%gridname grid--TTbar_pttcmc.root
%markerstyle 24
%markercolor 1
%reflinecolor 2
%reflinestyle 2
----- xxxx
```

New Steering File

```
debug = true
pdf_directory = PDF
data_directory = Data

grid_directory = Grids

;=====
; Graphing Options
;=====
[GRAPH]
; plot_band =
; plot_error_ticks =
plot_marker = true
plot_staggered = true
label_sqrt_s = true
x_legend = 0.9
y_legend = 0.9
; ratio_title =
ratio_style = convolute/data
overlay_style = convolute, data
display_style = overlay, ratio
; y_overlay_min =
; y_overlay_max =
; y_ratio_min =
; y_ratio_max =

;=====
; PDF Options
;=====
[PDF]
pdf_steering_files = good_test.txt

;-----
; NOTE:
;
; The following options will OVERRIDE the corresponding
; options in ALL the chosen PDF Steering Files above
```

Mont Salève



Mont Jura



Bern



Einstein's Apartment

