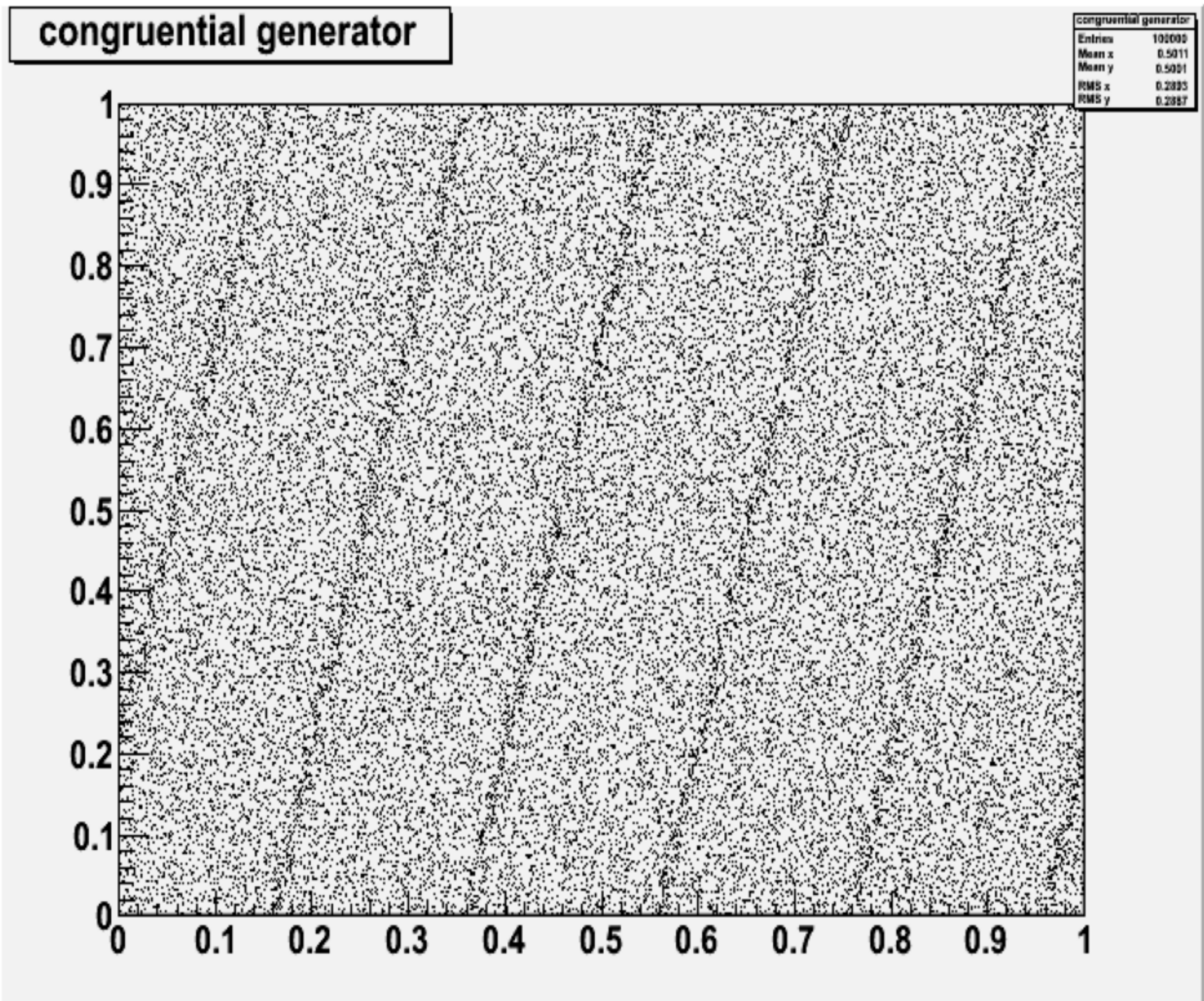
Monte Carlo School 2015
13-17 April 2015
DESY, Hamburg

Wrapping-up exercises

- Schedule:
  - Tuesday - Exercise 1:
    - Random numbers
    - MC method
    - MC integration
  - Wednesday - Exercise 2:
    - Sudakov form factor
    - MC solution of evolution equation
  - Thursday - Exercise 3
    - Calculation & simulation of Higgs production
    - Using MC solution of evolution equation → calculation of pt spectrum of Higgs at LHC

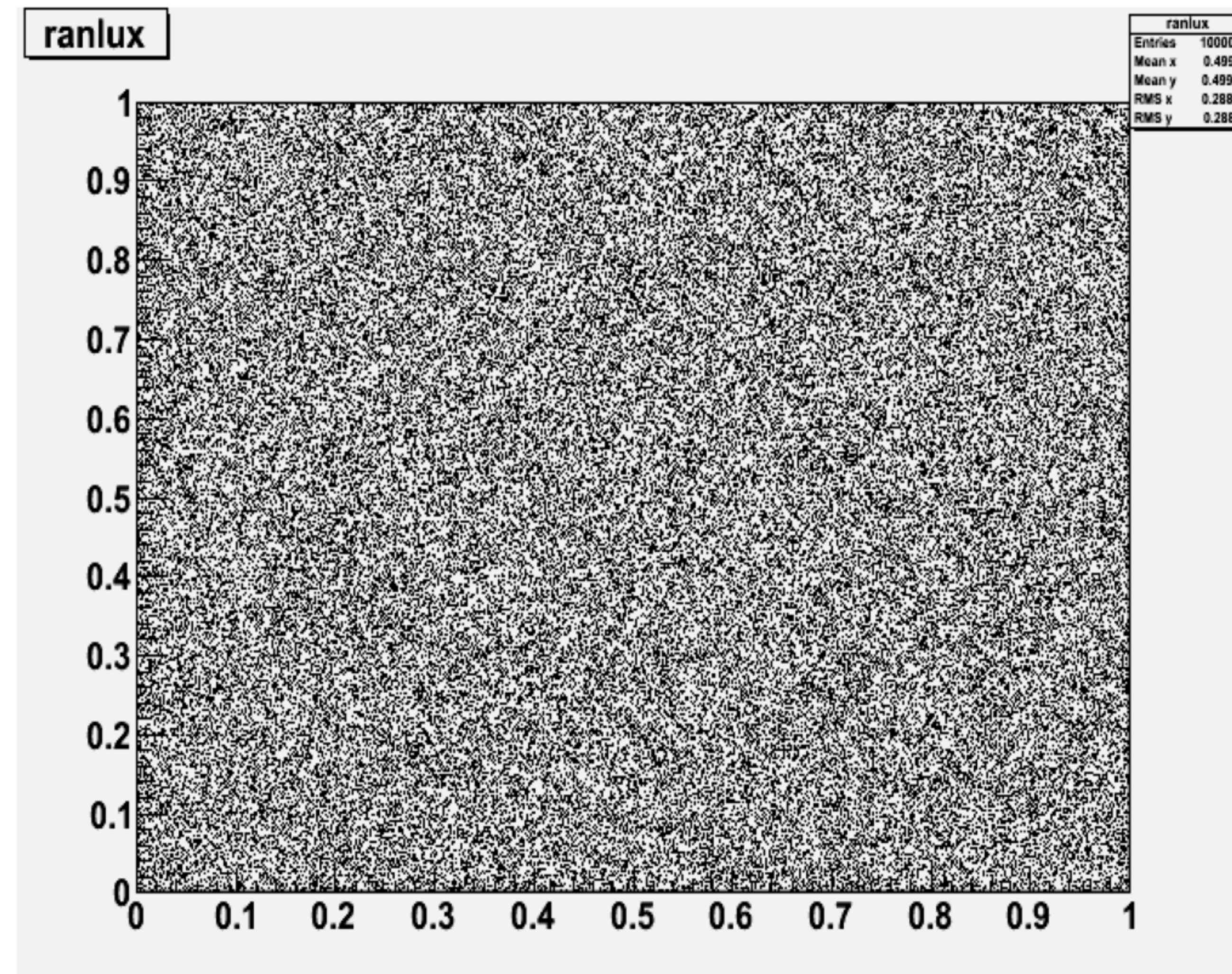
Randomness tests

- Congruential generator



- RANLUX

M. Lüscher, A portable high-quality random number generator for lattice field theory simulations, Computer Physics Communications 79 (1994) 100
http://luscher.web.cern.ch/luscher/ranlux/index.html



➔ RANLUX much more sophisticated. Developed and used for QCD lattice calcs

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Central Limit Theorem

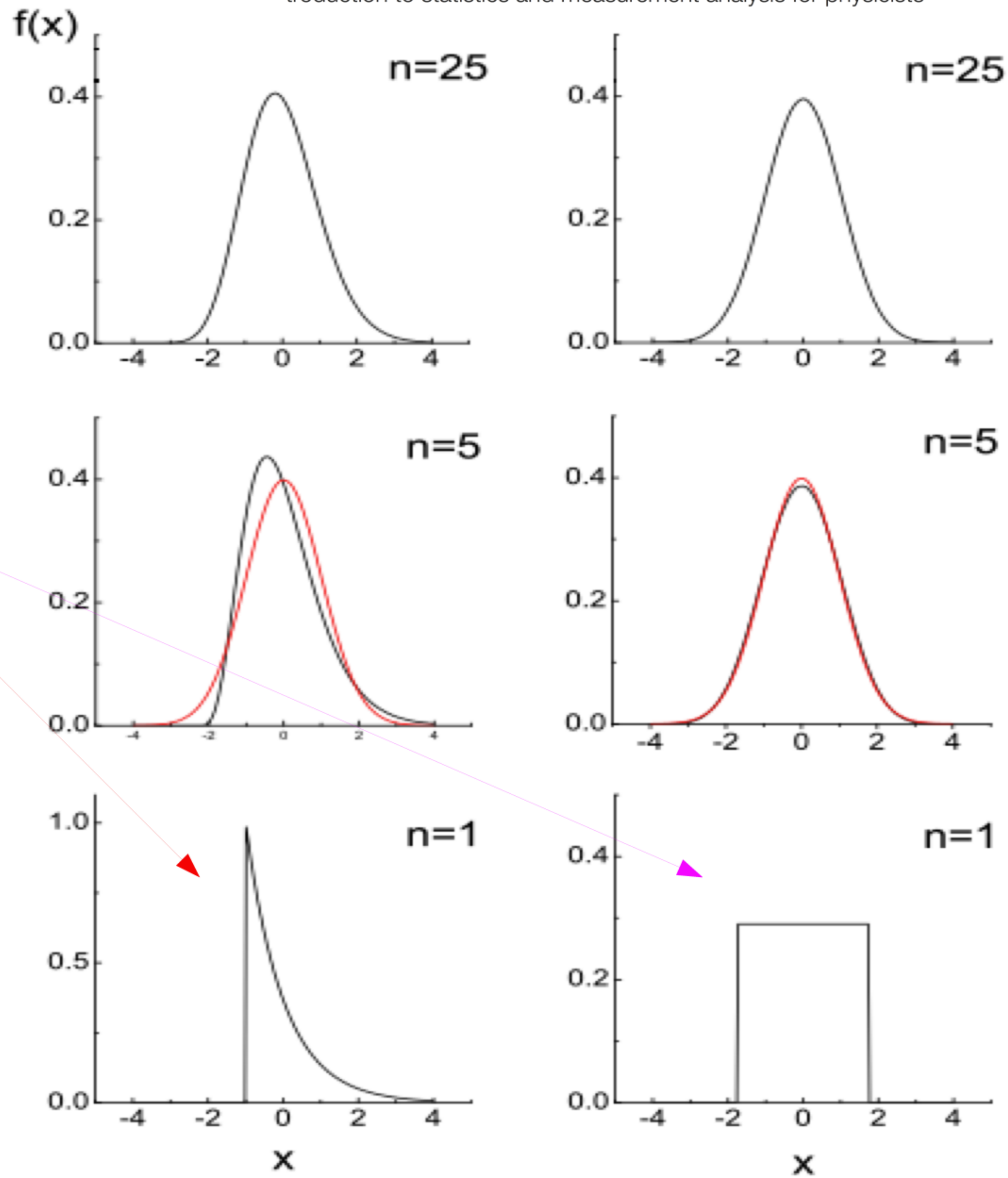
- Central Limit Theorem
  for large N the sum of independent random variables is always normally (Gaussian) distributed

➔ for any starting distribution

➔ for uniform distribution

➔ for exponential distribution

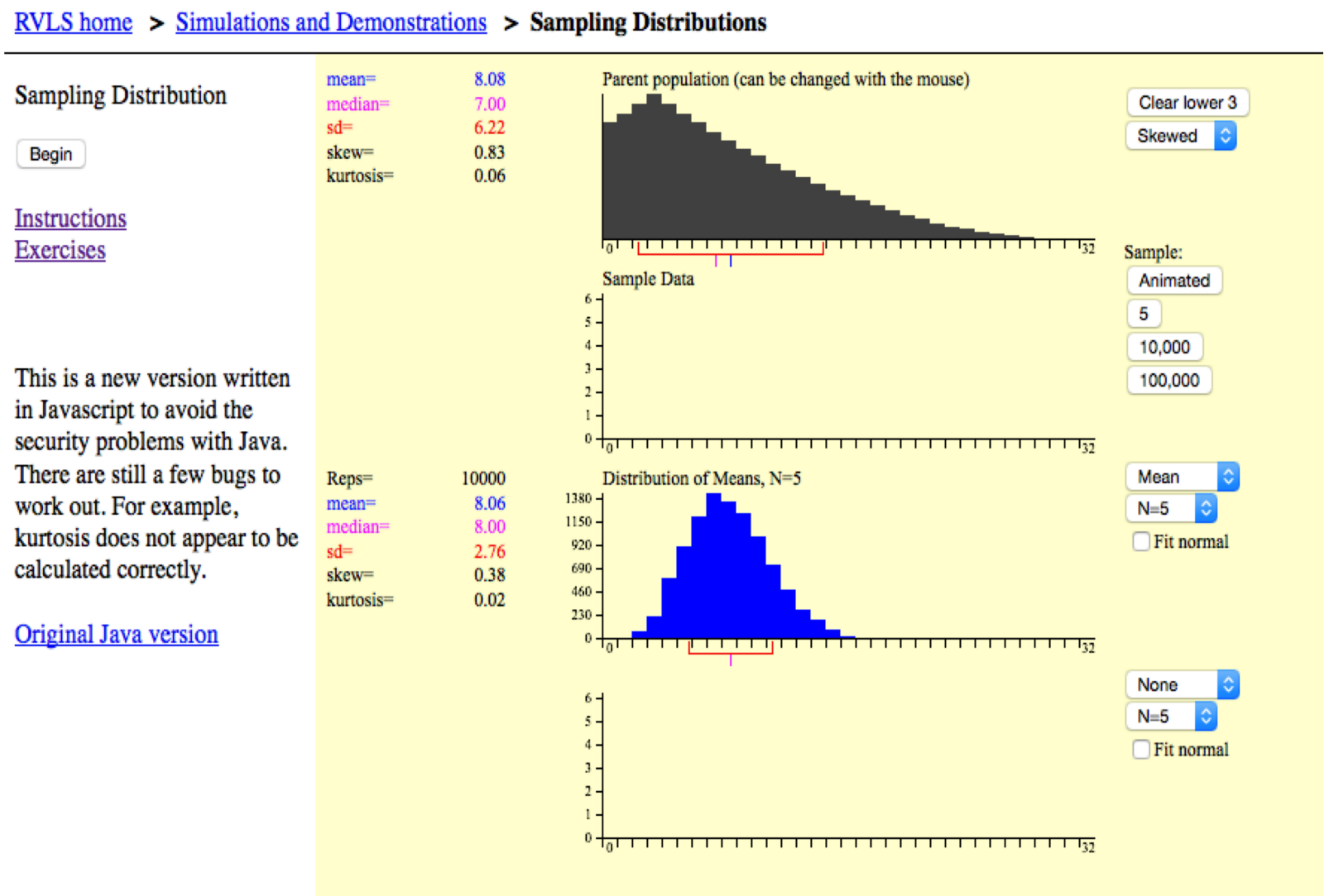
G. Bohm, G. Zechln
troduction to statistics and measurement analysis for physicists



Central Limit Theorem

http://onlinestatbook.com/stat_sim/sampling_dist/index.html

Thanks to Juan, who found this page



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Importance Sampling

- MC calculations most efficient for small weight fluctuations:

  $f(x)dx \to f(x)\ dG(x)/g(x)$

- chose point according to g(x) instead of uniformly
- f is divided by $g(x) = dG(x)/dx$
- **generate x according to:**

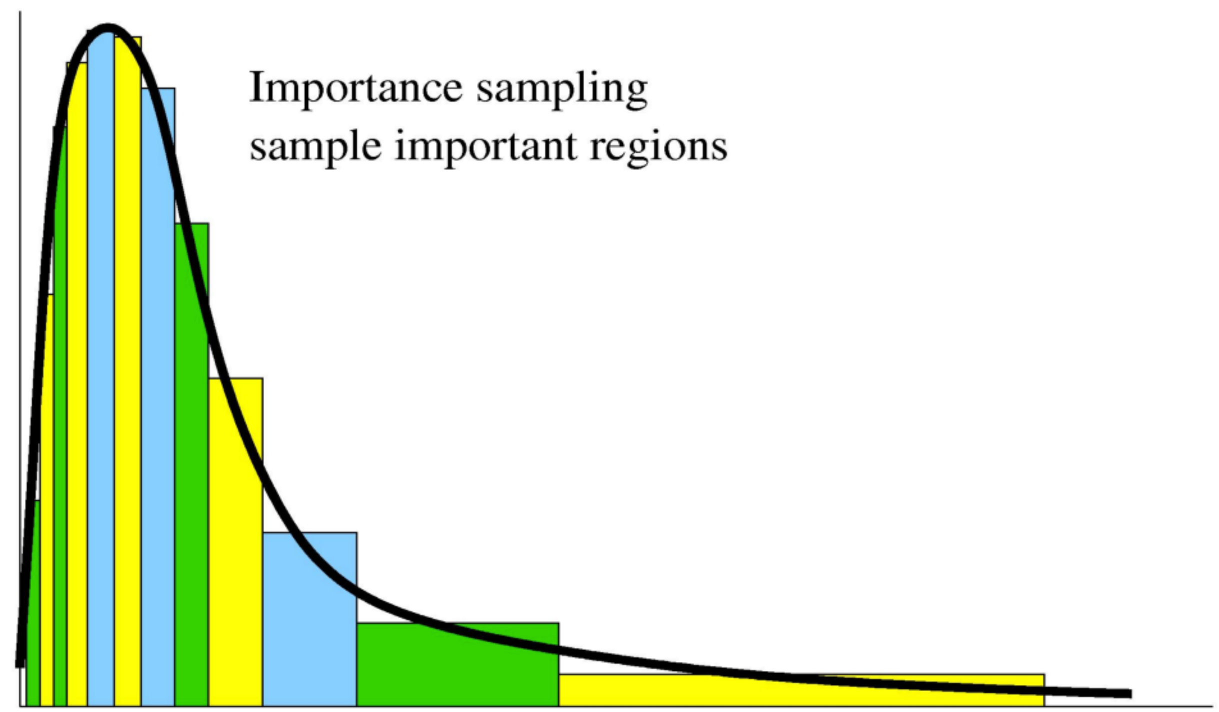
$$R \int_a^b g(x')dx' = \int_a^x g(x')dx'$$

- relevant variance is now V(f/g):

  small if g(x) ~ f(x)

- how-to get g(x)

  (1) g(x) is probability: g(x) > 0 and $\int dG(x) = 1$
  (2) integral $\int dG(x)$ is known analytically
  (3) *G(x)* can be inverted (solved for *x*)
  (4) f(x)/g(x) is nearly constant, so that *V(f/g)* is small compared to V(f)



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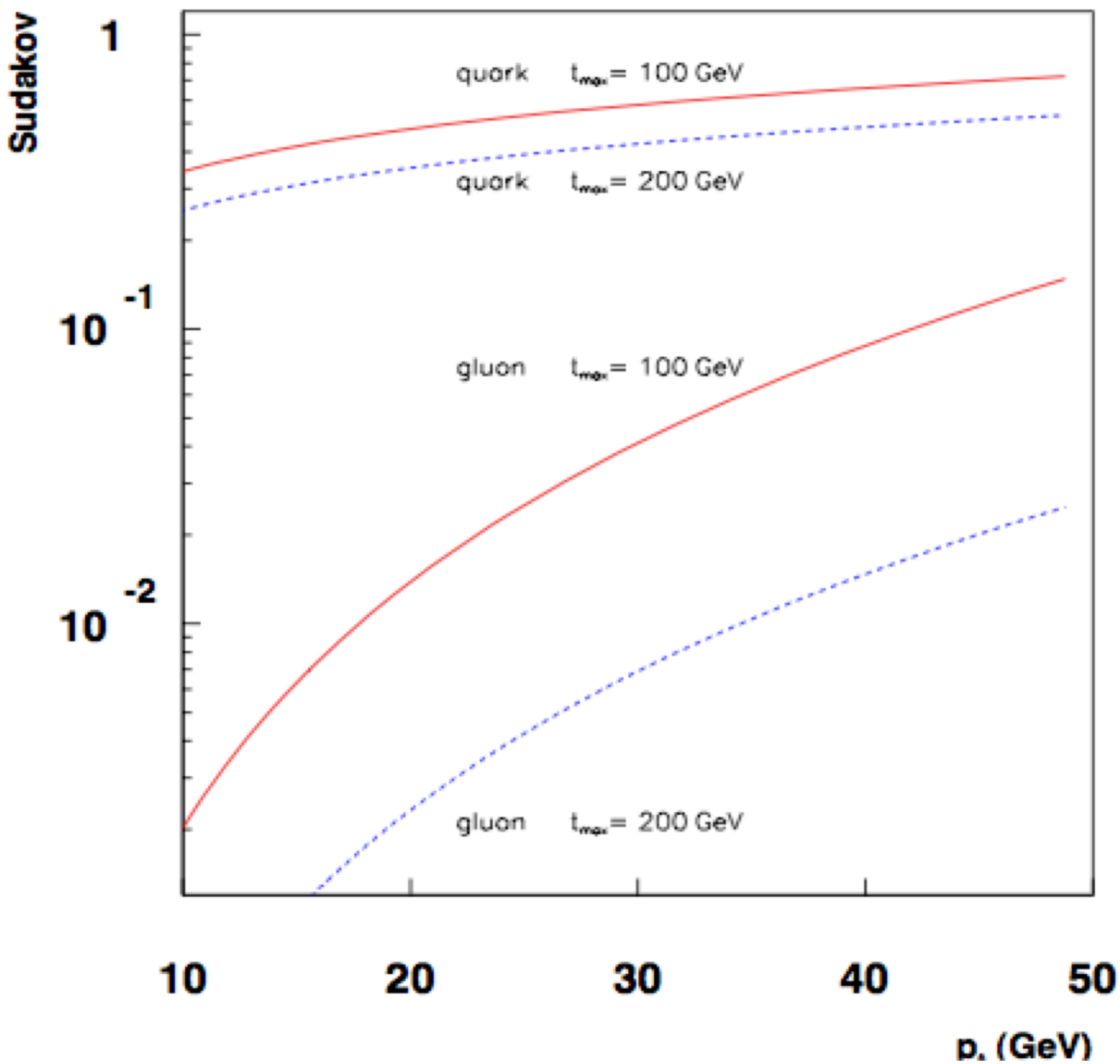
Sudakov form factors



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Evolution equation and MC

$$f(x,t) = f(x,t_0)\Delta_s(t) + \int \frac{dz}{z} \int \frac{dt'}{t'} \cdot \frac{\Delta_s(t)}{\Delta_s(t')} \tilde{P}(z) f\left(\frac{x}{z}, t'\right)$$

- solve integral equation via iteration:

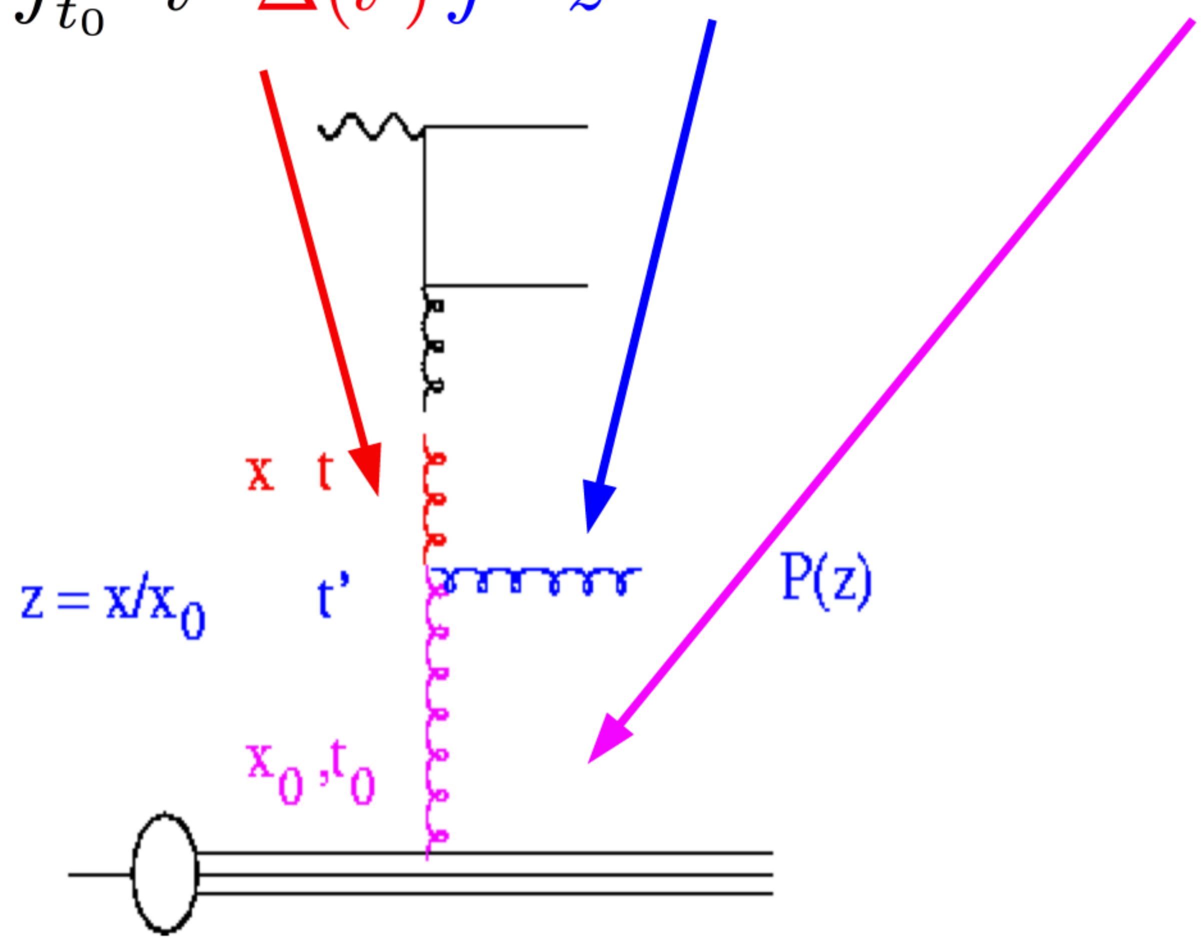
from t' to t w/o branching

branching at t'

from t_0 to t' w/o branching

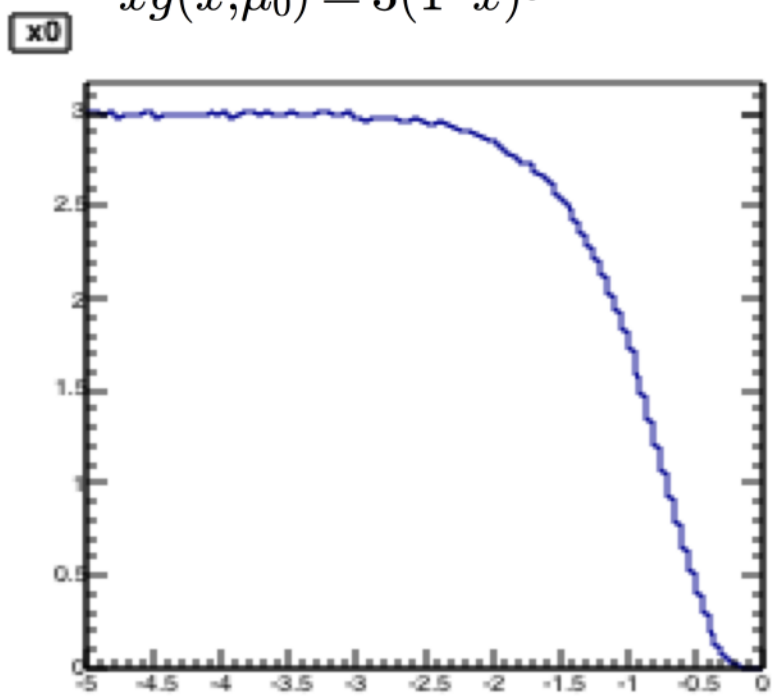
$$f_0(x,t) \quad = \quad f(x,t_0)\Delta(t)$$

$$f_1(x,t) \quad = \quad f(x,t_0)\Delta(t) + \int_{t_0}^{t} \frac{dt'}{t'} \frac{\Delta(t)}{\Delta(t')} \int \frac{dz}{z} \tilde{P}(z) f(x/z, t_0)\Delta(t')$$

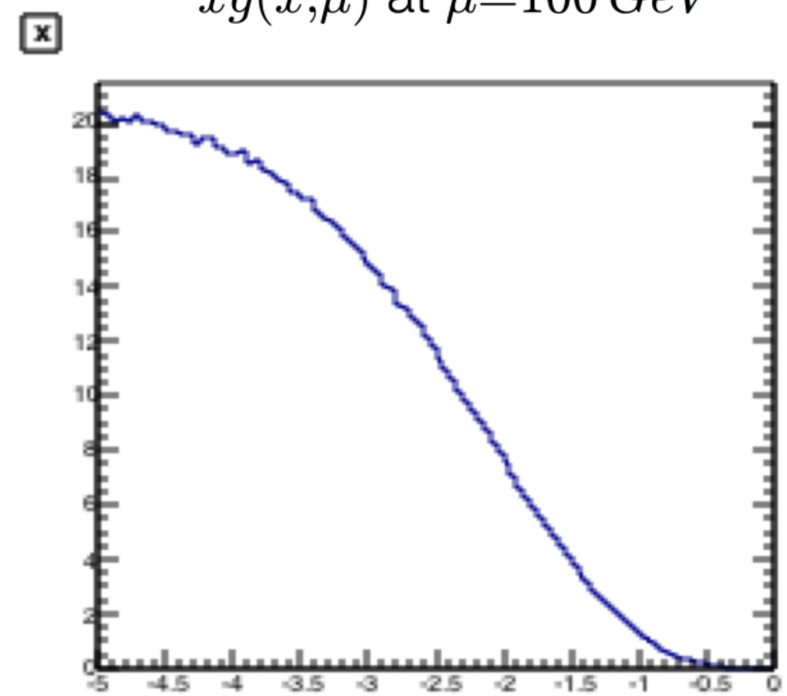


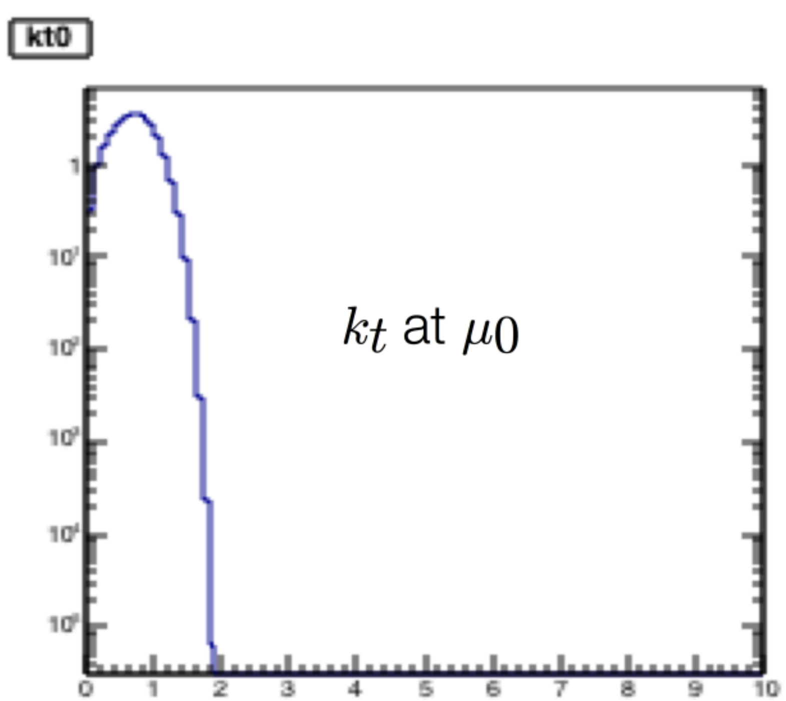
Evolution of gluon density

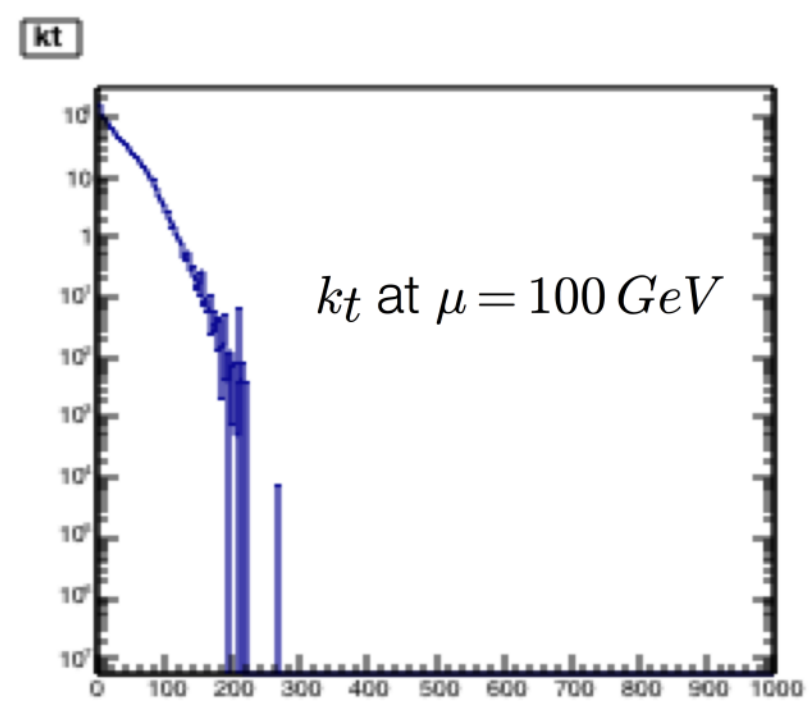
Starting distribution:
$xg(x, \mu_0) = 3(1-x)^5$



Evolved distribution:
$xg(x, \mu)$ at $\mu = 100\, GeV$

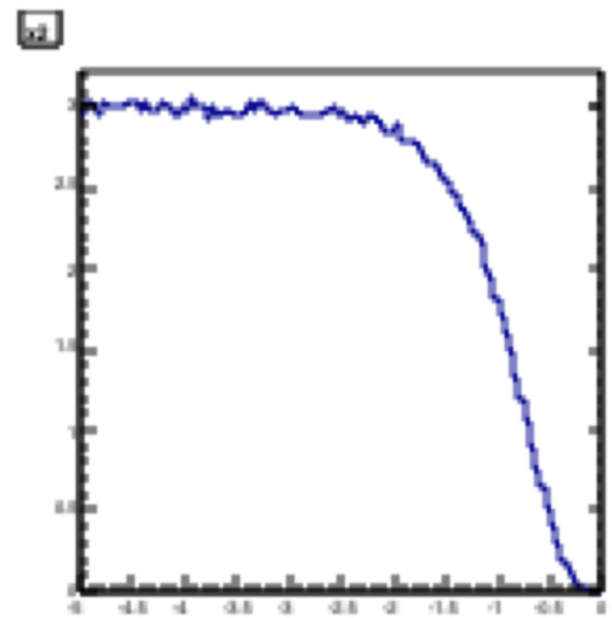


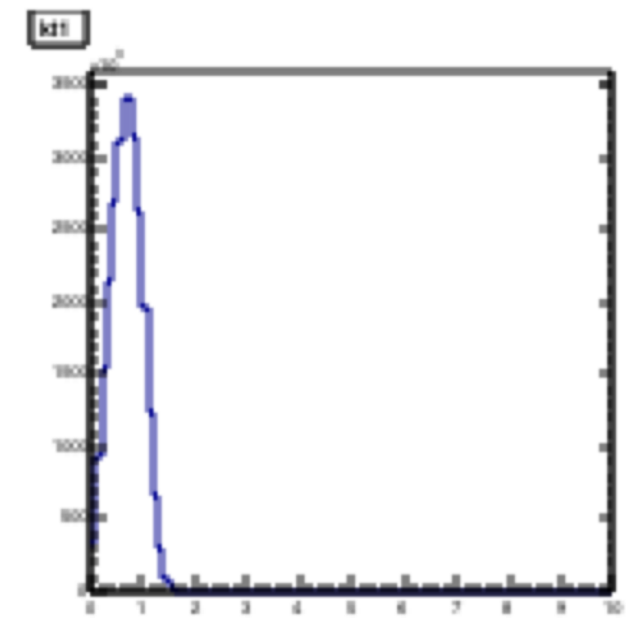




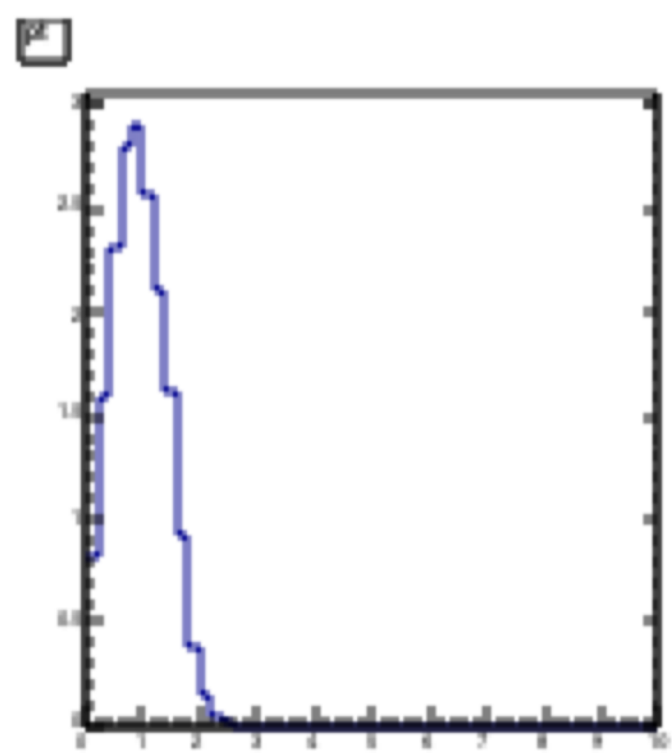
Higgs p_t at LO w/o evolution

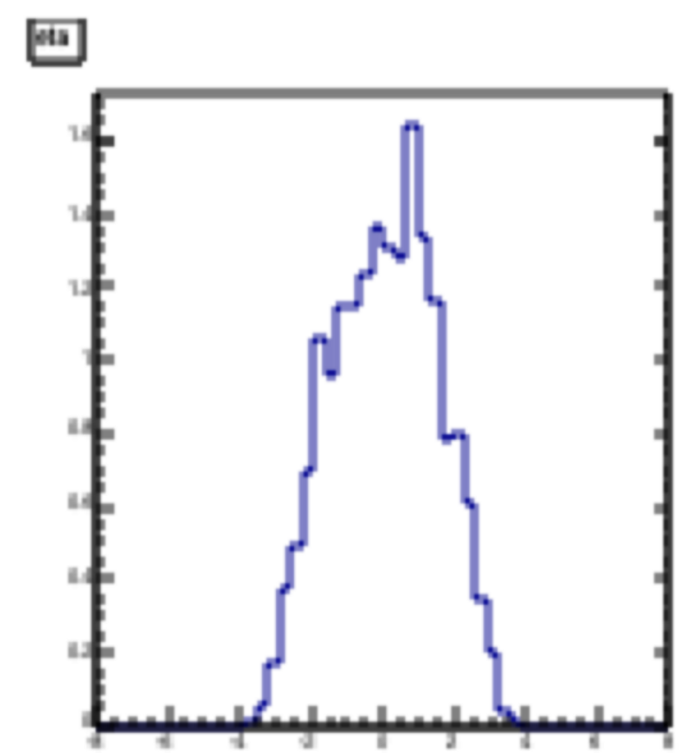
Gluon distribution





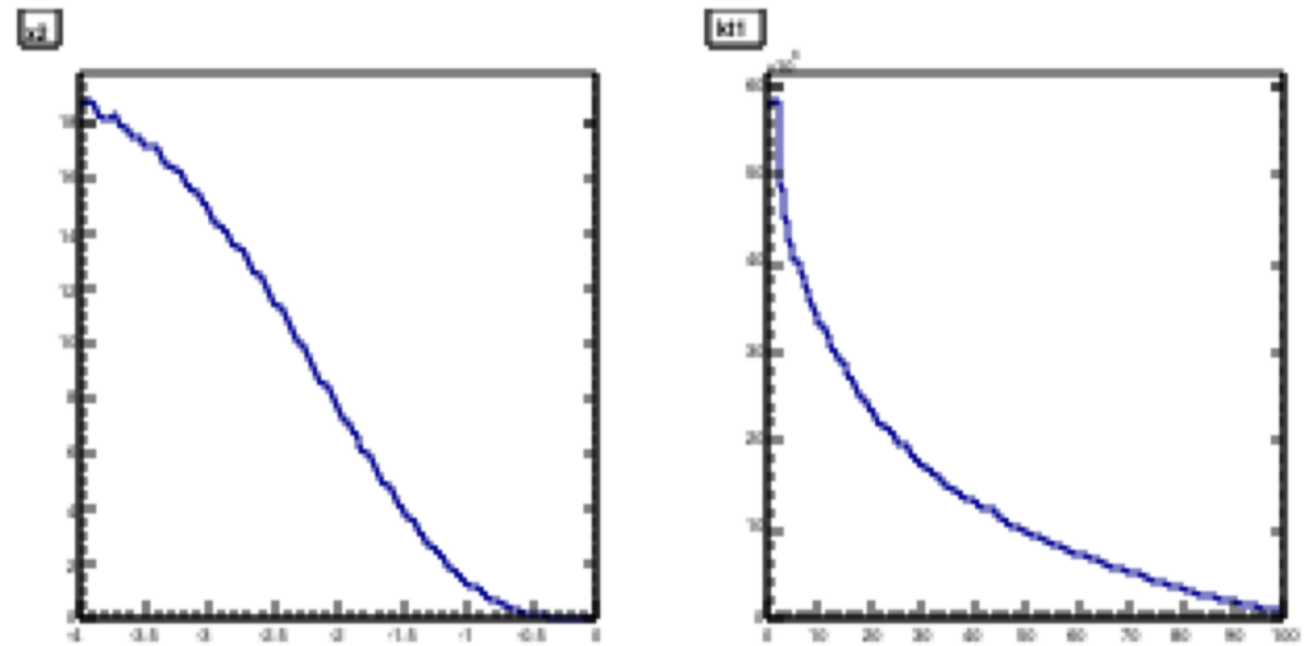
Higgs p_t and y





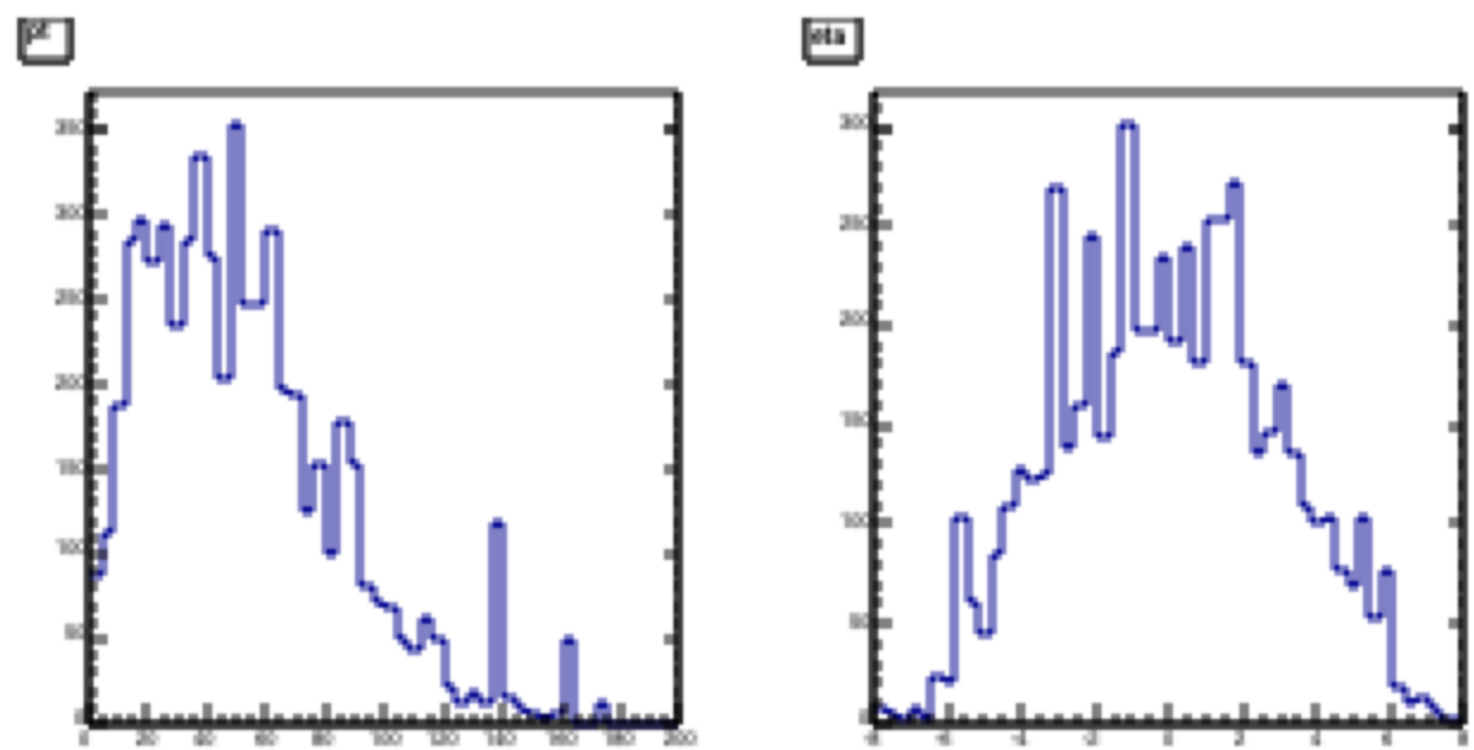
Higgs p_t at LO with evolution

Gluon distribution



Higgs p_t and y

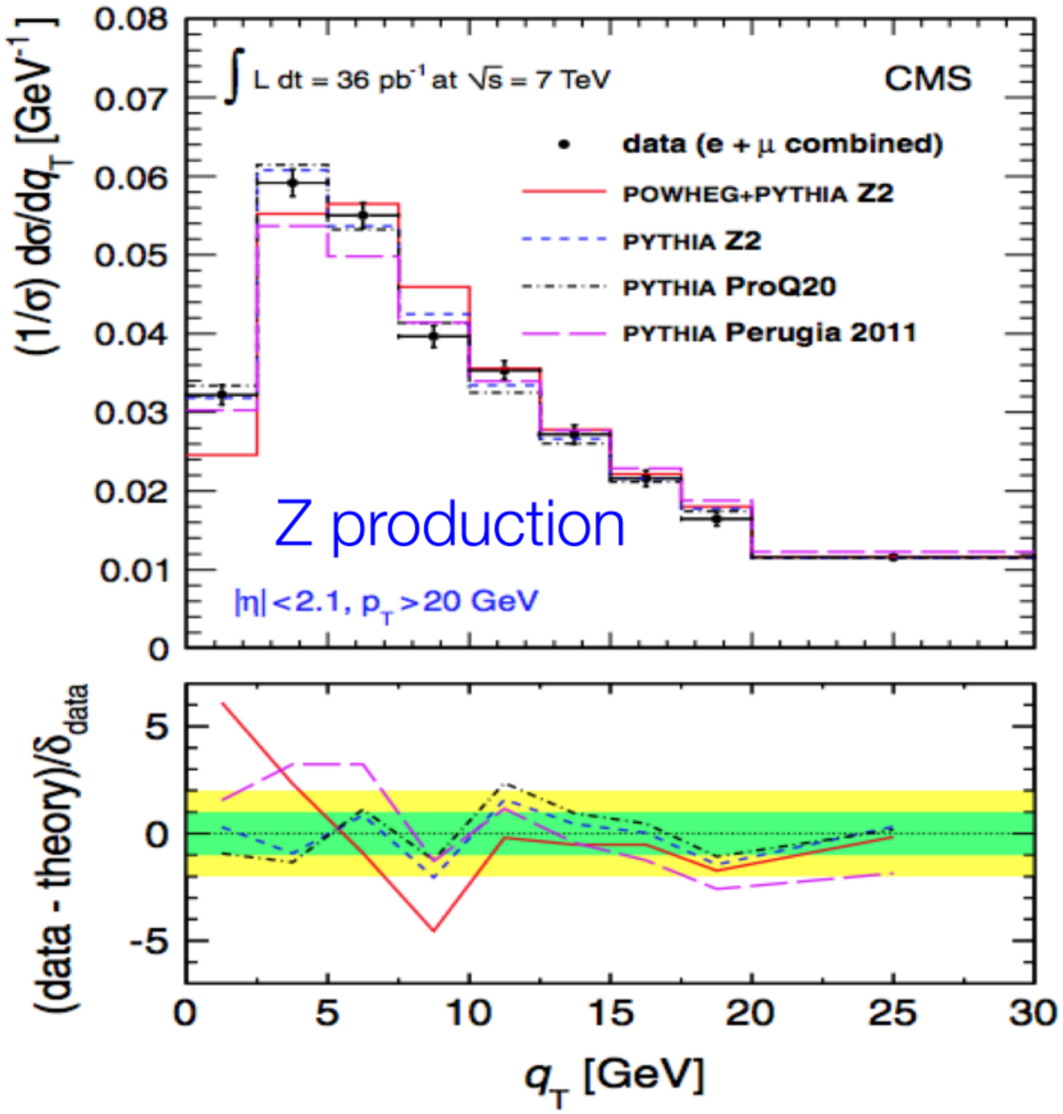
- peak at $p_t \sim 20\ GeV$
- tail to large pt



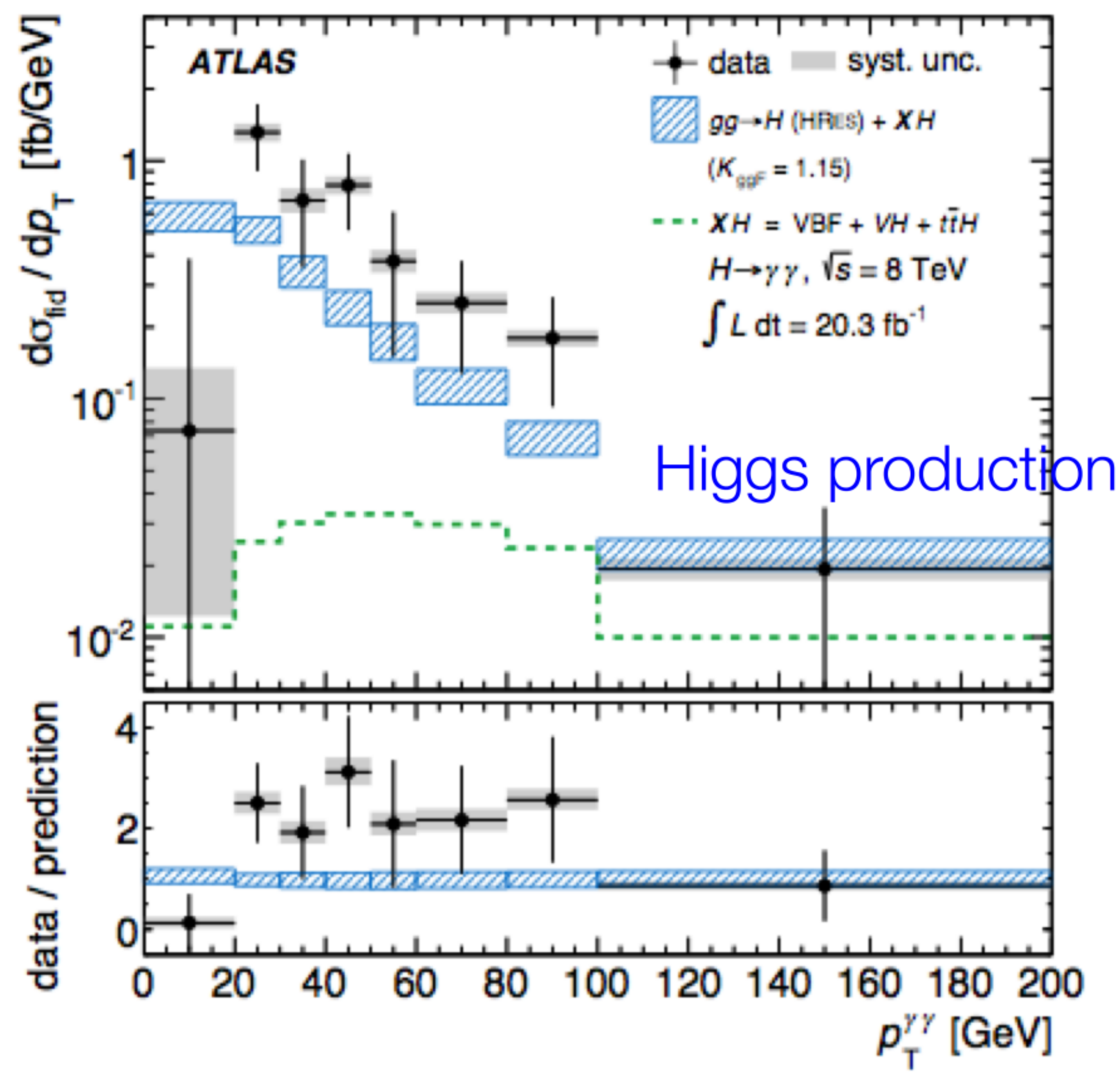
Transverse Momentum of Z and Higgs

CMS Coll. Measurement of the Rapidity and Transverse Momentum Distributions of Z Bosons in pp Collisions at√s = 7 TeV. Phys.Rev., D85:032002, 2012.

CMS Coll., PRD 85, 032002 (2012)



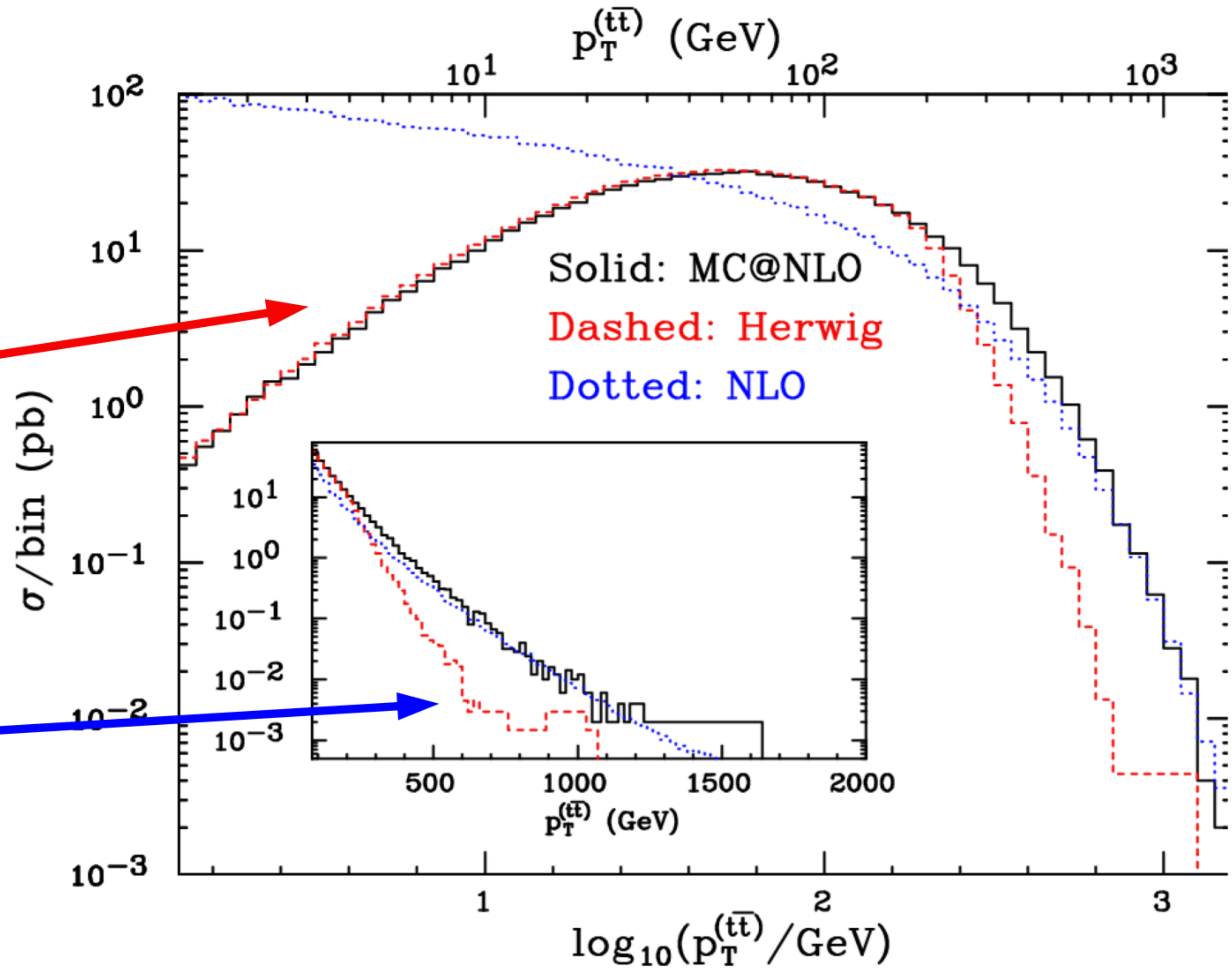
Differential cross sections of the higgs boson measured in the diphoton decay channel using 8 TeV pp collisions. ATLAS arXiv 1407.4222



Small pt in heavy quark prod.

Frixione et al, hep-ph/035252

- Compare fixed NLO calculation of top production with resummed calculation from Monte Carlo
- Similar effects at small pt are observed: Suppression of xsection at small pt
- At large pt, resummation is too small, NLO is better



End

- Exercises & solutions are on indico page link

- If there are questions (even later …)
  - please contact us: hannes.jung@desy.de

- Comments ?

- Questions ?