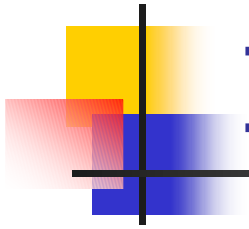
QCD event generators with next-to-leading order matrix-elements and parton showers

Yoshimasa Kurihara
(KEK)

Les Houches 2003
QCD/MC working group
02/June/2003 @ Les Houches

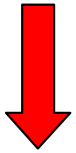
Y. Kurihara et al., Nucl. Phys B 645 (2003) 301



Introduction

- LHC Experimental requirement

  LO-QCD Event generator+K-factor



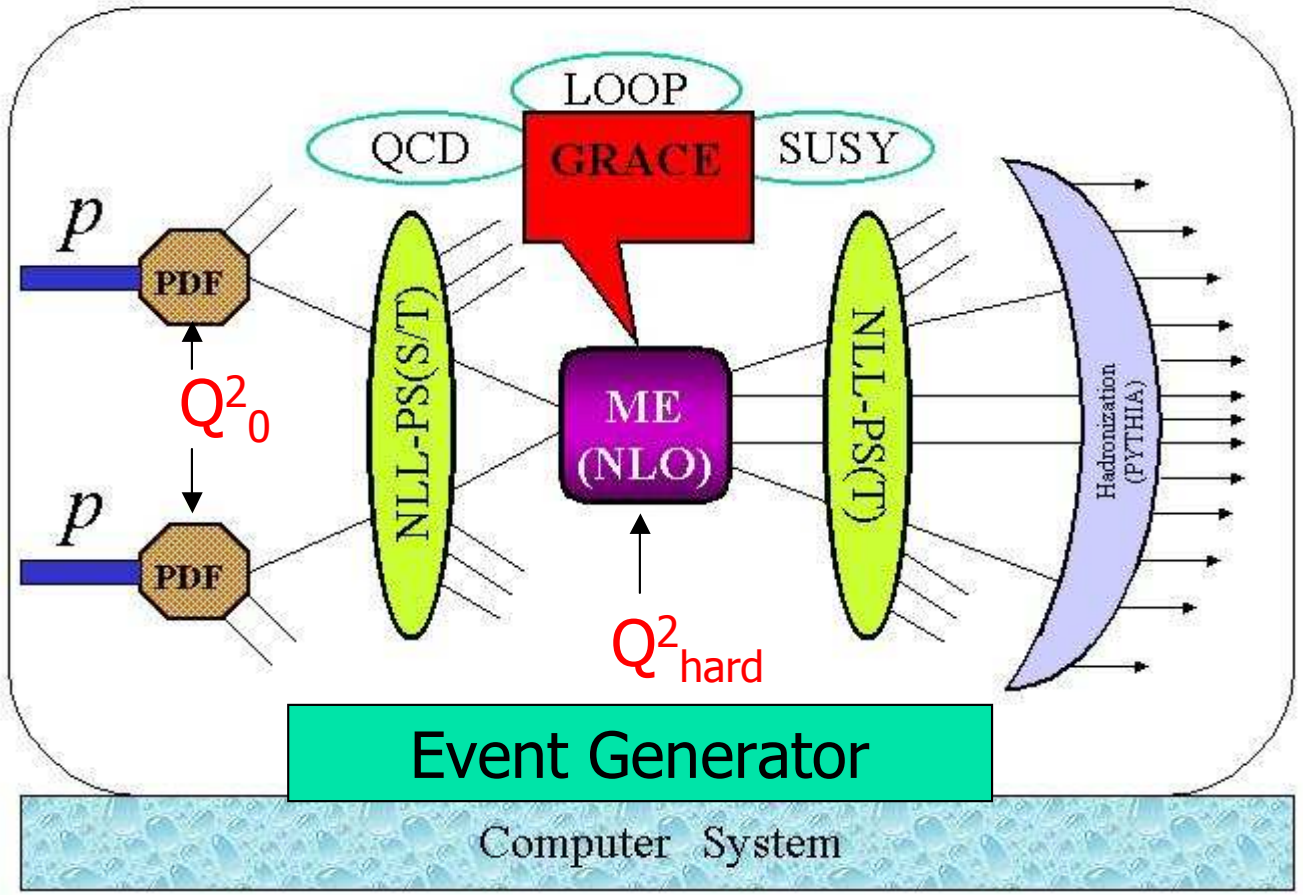
Obviously not enough!

We need
NLO Event generator!

Difficulties → Solusions

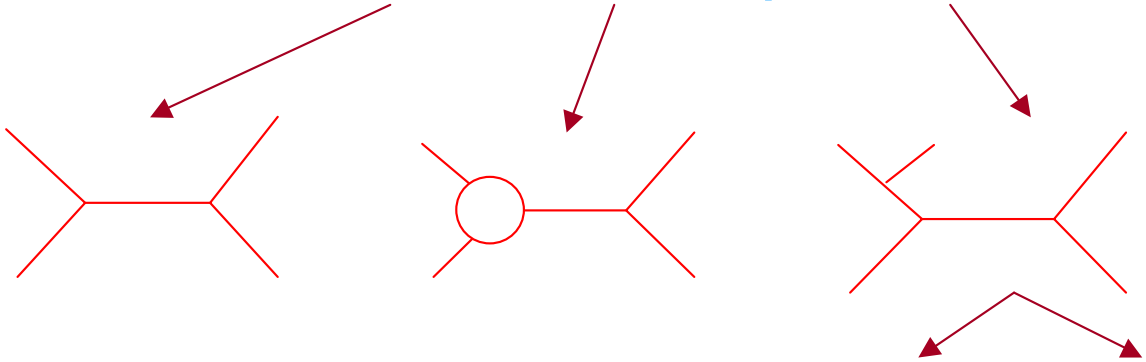
- Large number of diagrams → GRACE
- Numerical instability due to a collinear singularity
- Double counting between ME and PDF/PS → LL-subtraction + Parton Shower
- **Negative weight** → **Improved SPRING**

Grand Design



NLO Cross sections

$$\sigma_{NLO}=\sigma_{tree}+\sigma_{loop}+\sigma_R$$



$$=\sigma_{tree}(1+\delta_V+\delta_{s/c})+\sigma_{vis}$$

δ_V : Virtual (loop) correction

$\delta_{s/c}$: Soft/Collinear correction

σ_{vis} : Visible jet cross section

Matrix Elements: Tree

- Tree diagrams

$M_0(1,2 \to 1,2\cdots,n)$: Born

$M_R(1,2 \to 1,2\cdots,n,n+1)$: Real radiation

GRACE: Automatic generation up to n≅6

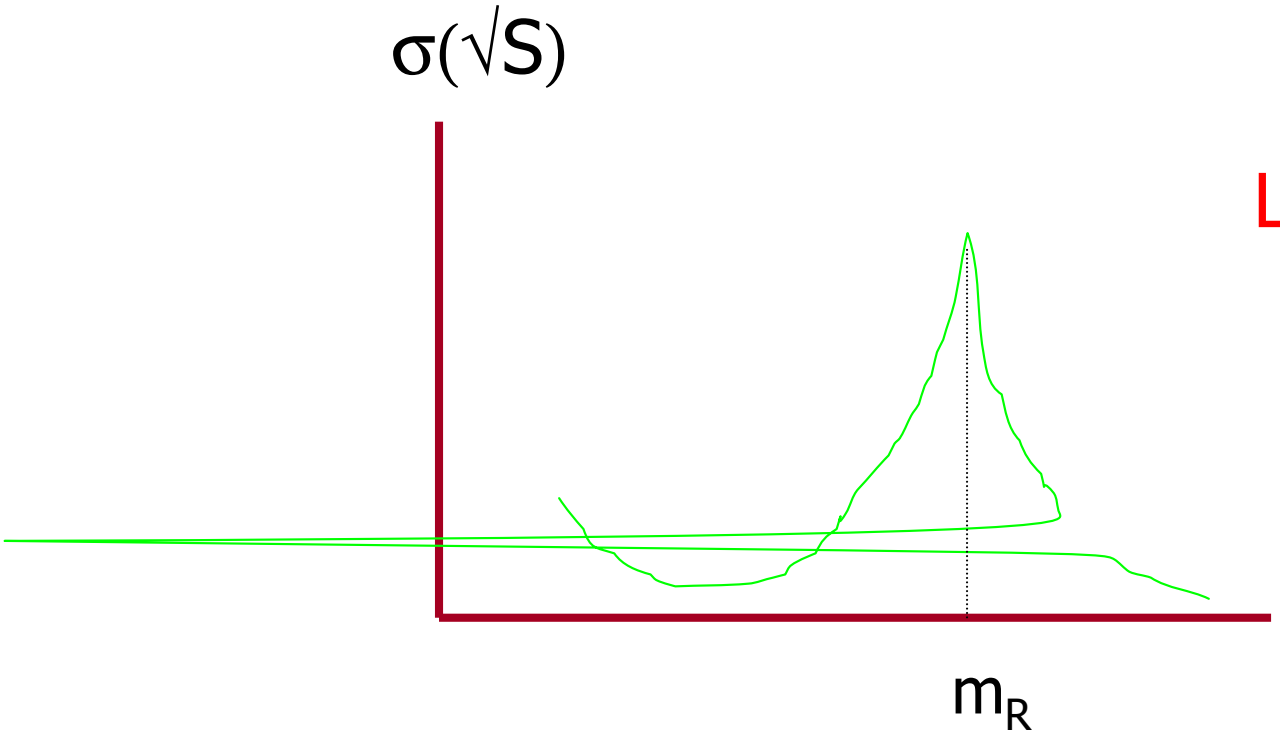
↑

Diagrams & FORTRAN source code

CHANEL: Numerical Helicity Amplitude

Parton Shower

forward evolution



Low efficiency?

$$\sqrt{S}=\sqrt{x_1 \cdot x_2 \cdot S_0}$$

Parton Shower: x-deterministic Method

Q^2-evolition ⟸ Sudakov form factor $\Pi(Q_2^2, Q_1^2)$

After the evolution (n-times)

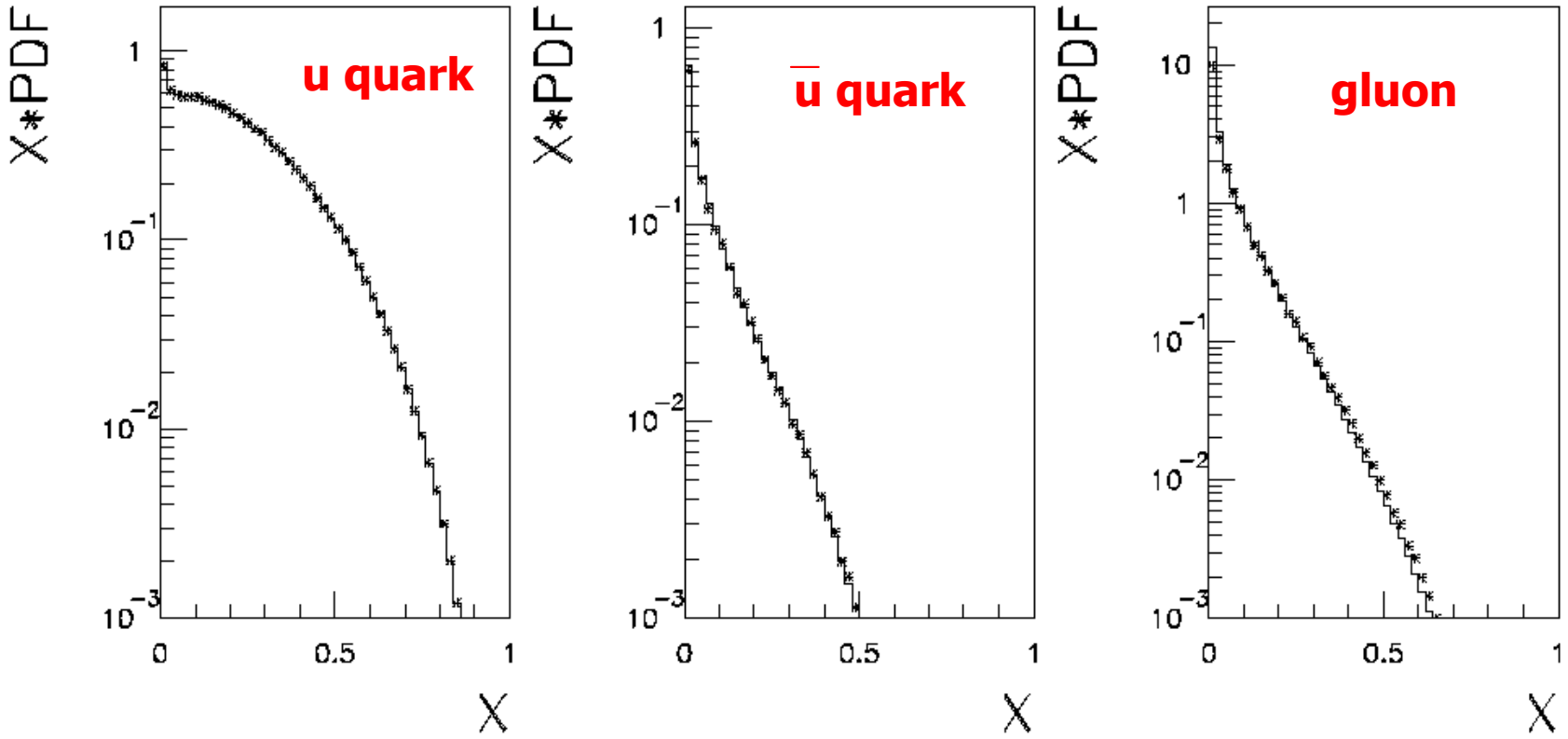
$$W = \frac{1}{W_0}\prod_{i=1}^{n} P(x_i) F_{PDF}(x_0) dx_i dx_0 \delta\left(x - x_0 \prod_{j=1}^{n} x_j\right) dx$$

$$= \frac{1}{W_0}\prod_{i=1}^{n} P(x_i) F_{PDF}(\tilde{x}_0) \frac{dx_i dx}{\prod_{j=1}^{n} x_j}$$

x-deterministic

$$W_0 = \prod_{j=1}^{n} \int_0^1 P(x_j) dx_j, \qquad \tilde{x}_0 = \frac{x}{\prod_{j=1}^{n} x_j}$$

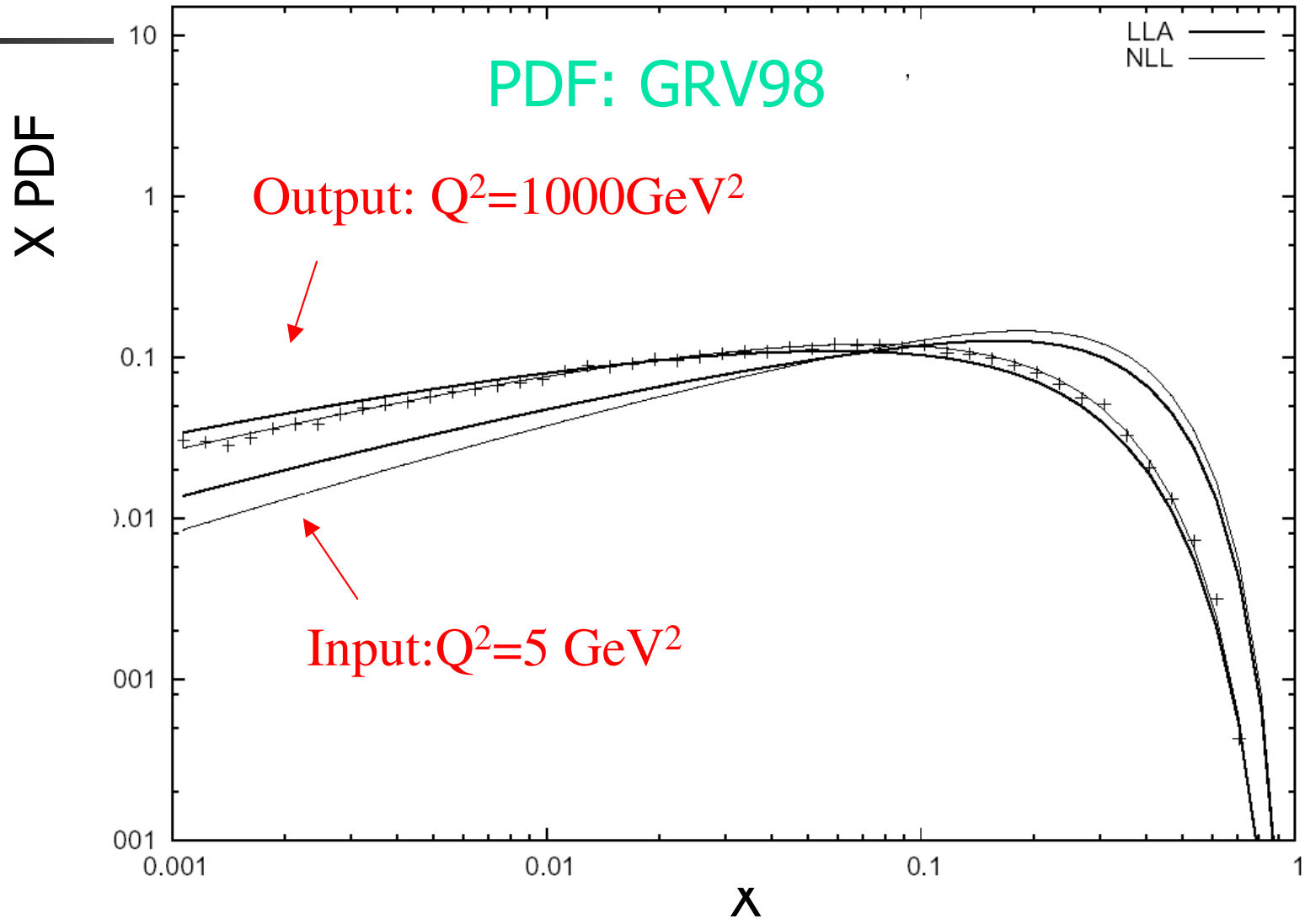
Parton Shower:Test



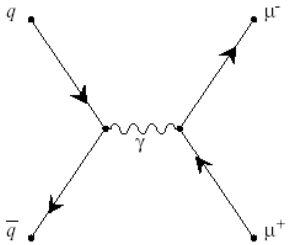
□ : Cteq5L　　* : PS　　Q2: 5GeV→100GeV

NLLPS

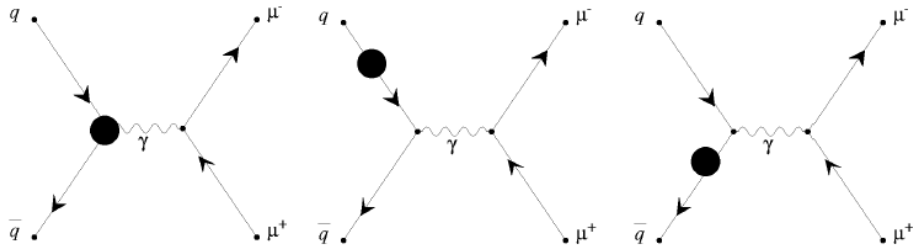
non-singlet



Drell-Yan Process

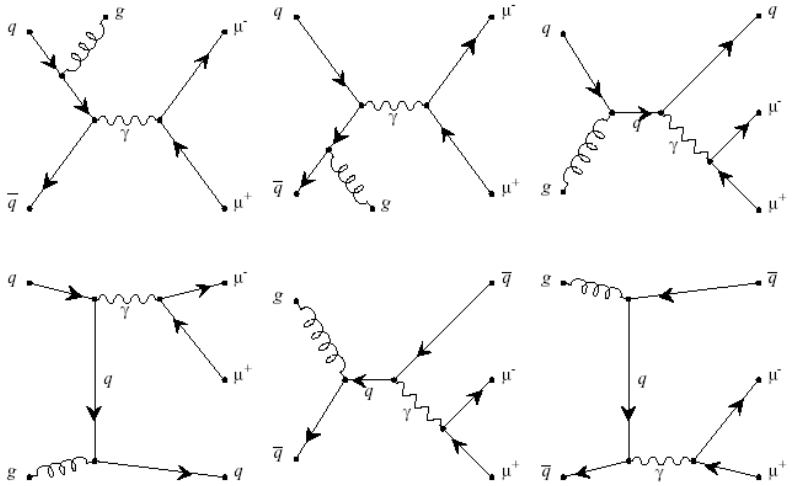


Born diagram



Loop diagrams

Real radiation diagrams



Drell-Yan Process

Parameters

Process: $\bar{p}p \rightarrow \mu^+\mu^-$

$\sqrt{s_{pp}}$=2 TeV

PDF : Cteq5L ($E_{scale}=\sqrt{s_{\mu\mu}}$)

Cuts: $\sqrt{s_{\mu\mu}}$>10GeV

Results

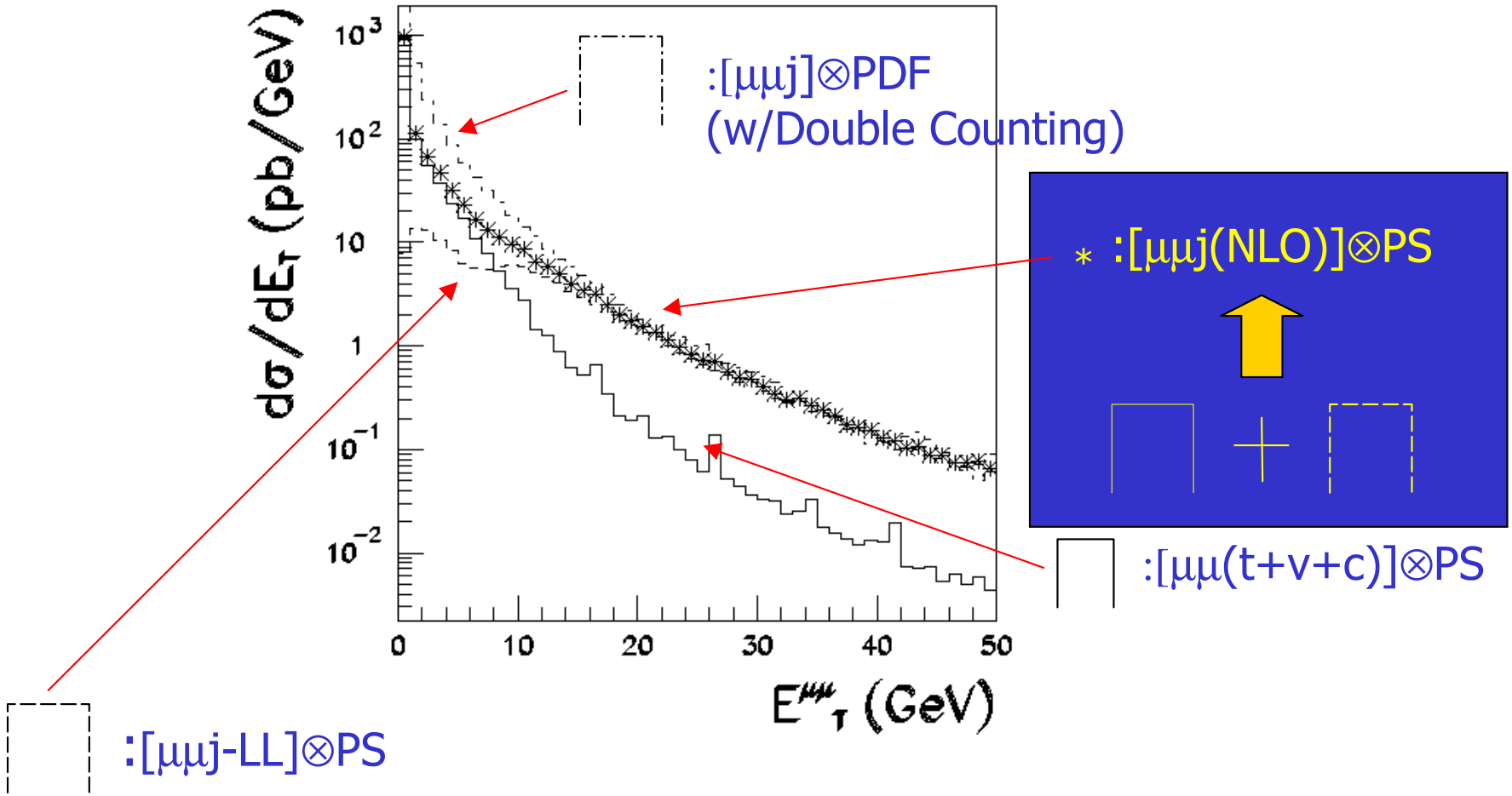
s_{tree}=1.026 nb

s_{NLO}=1.288 nb (K-factor=1.25)

$s_{P/S}$= $s_{LL\text{-}Sub}$

Q^2_c independent

E_T of μ-pair system



pp→zz+jet process

Process: pp→zz+jet

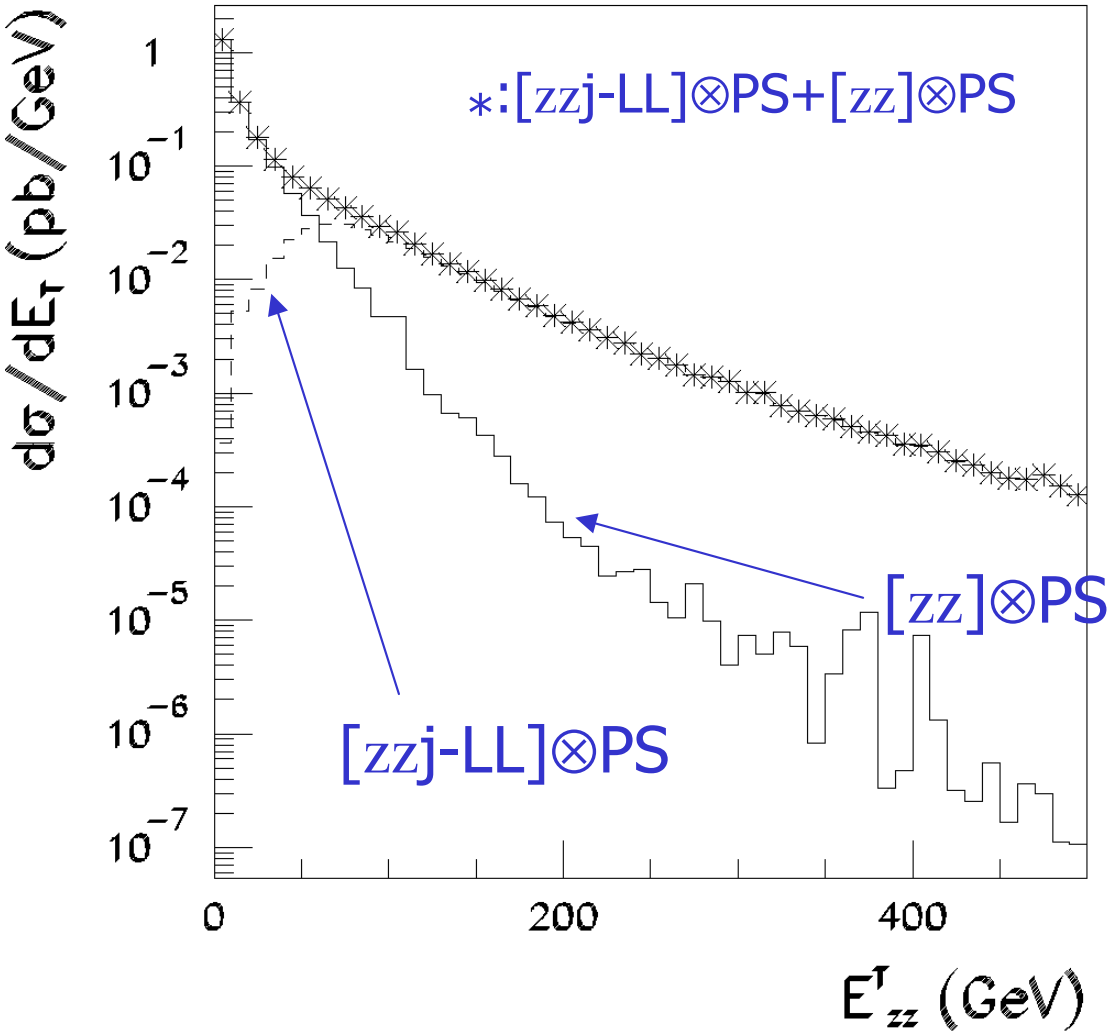
$\sqrt{s_{pp}}$=14 TeV

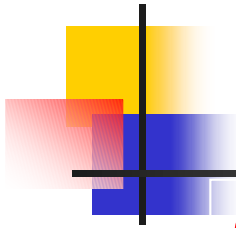
PDF : Cteq5L

(E_{scale}=Mz+$\overline{p_T}$)

Cuts: non

E_T of the zz-system





Summary

(1) Matrix Elements
- Automatic generation by GRACE

(2) Parton Shower
- x-deterministic PS at LL
- NLL-PS is under development

(3) Soft/Collinear treatment
- LL-subtraction method

(4) Application
- Drell-Yan process
- W,Z+jets processes in future