Double Constrained Evolutions in a single Monte Carlo for the DY-type processes – A prototype

HERA-LHC Workshop, CERN, June 7-th, 2006

S. Jadach

`stanislaw.jadach@ifj.edu.pl`

IFJ-PAN, Kraków, Poland

The project is supported by EU grant MTKD-CT-2004-510126, realized in the partnership with CERN PH/TH Division

Outline

- Introduction, terminology
- Single QCD evolution in Cracow 2005/06
- CMC in a nutshell
- Mapping to 4momenta, single evolution
- Joining 2 single evolution into one gluonstrahlung MC (LL) for W/Z production:
  - Mapping, phase space parametrization
  - Basic distribution for double evolution
  - Realizing constraint on $\hat{s}$ at the 4-momenta level.
  - Preliminary MC results (rapidity and p_T of W/Z and emitted gluons.
- Summary, prospects, problems...

Acknowledgments, warnings....

I am indebted to all my colleagues in the INP Cracow group for discussion and encouragement in pursuing this work, especially to M. Skrzypek and P. Stephens.

I would like to thank CERN/PH/TH for hospitality and support in realizing our TOK project on the devolepment of Monte Carlo tols for LHC.

Presented new numerical results are very preliminary, only a few days/weeks old and may change.

Single “QCD Evolution” using Monte Carlo, various types

Evolution types and solution methods:

- **Evolution: Common forward, unconstrained, (ISR, FSR):**
  - **Method of solving: straightforward Markovian MC algorithm (MMC)**
- **Evolution: Constrained (ISR):**
  - **Method: Constrained MC algorithm, non-Markovian (CMC)**
  - **Method: “Backward evolution” MC algorithm, Markovian (PYTHIA, HERWIG,...)**

Terminology:

“Markovian MC’’: Emission multiplicity generated as last variable in the MC,

“Non-Markovian MC”: Emission multiplicity generated as first variable (or 2nd).

“Constrained evolution”: Final parton type and energy fraction x in the evolution are predefined, fixed. However, all the distribution can be identical as in the forward evolution (Markovian style).

Single QCD Evolution in Cracow using MC, 05/06

Single evolution programs/exercises far:

- Main emphasis on **CMC= C**onstrained **M**onte **C**arlo
- The long term aim is a high quality MC description of the QCD ISR in the W/Z production process at LHC. (DIS in the scope).
- **MMC** programs, **M**arkovian**M**onte **C**arlos, are developed in parallel and used as calibration tool for testing MMC.
- MMC programs implement presently:
  - DGLAP LL and NLL (xchecked with QCDnum16 and APCHEB to within 0.2%),
  - CCFM/HERWIG LL evolution with options: $\alpha_S(q(1-z))$, $\epsilon_{IR} = q_0/q$, $q_{stop} = x_0 q_{max}$, Quark-Gluon transitions. Mapping into 4-momenta.
- **CMC** programs feature presently:
  - DGLAP LL (xchecked with MMC and QCDnum16), Q-G transitions!
  - CCFM/HERWIG LL evol. (xchecked with MMC), options: $\alpha_S(q(1-z))$, $\epsilon_{IR} = q_0/q$, $q_{stop} = x_0 q_{max}$, Quark-Gluon transitions (not yet for $q_{stop} = x_0 q_{max}$). Mapping into 4-momenta.

CMC in a nutshell

- **Mapping of evolution time $t_i \to s_i$ and $z_i \to y_i$, such that Jacobian eliminates completely the (simplified) kernel $zP_{ff}(z,t)$**
- **Ordering in s_i temporarily removed**
- **The constraint $\delta(z - \prod z_i)$ is eliminated/fulfilled by means of the parallel shift $y_i \to y_i - Y$ (for DGLAP rescaling in the mom. space, $y = \ln(1-z)$).**
- **Quark-Gluon transitions by "brute force" method using general purpose FOAM simulator.**
- **Appropriate correcting MC weights applied at the end.**
- **For more details see my talks in previous HERA-LHC and other places, http://jadach.web.cern.ch/jadach/ and http://arxiv.org/abs/hep-ph/0504263**

Variable Mapping

$$\int_x^{1-\varepsilon(t)} dz_i \int_{t_0}^{t} dt_i \, \mathcal{P}^{\Theta}_{kk}(t_i, z_i) = h_k \int_{\rho(t_0-t)}^{\rho(\ln(1-x))} dy_i \int_0^1 ds_i \; 1, \quad i = 1, 2, ..., n,$$

$$z_i(y_i) = 1 - \exp(\rho^{-1}(y_i)),$$

$$\hat{t}_i(s_i) = \hat{t}_0 \left(\frac{\hat{t} + \ln(1 - z_i)}{\hat{t}_0} \right)^{s_i} - \ln(1 - z_i).$$

where

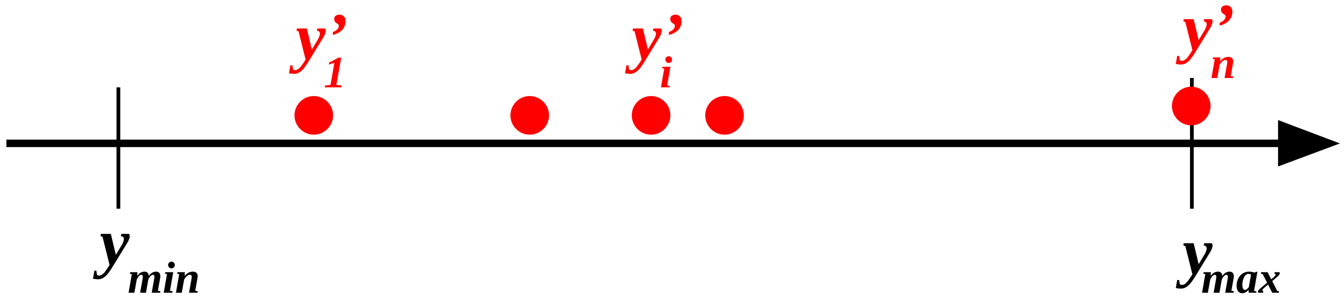
$$\rho(v) \equiv (\hat{t} + v) \ln(\hat{t} + v) - v - v \ln \hat{t}_0 - \hat{t} \ln \hat{t}, \quad \hat{t} \equiv t - t_\Lambda = \ln Q - \ln \Lambda_0.$$

IMPORTANT: ρ^{-1} is not analytical!
Inversion has to be done numerically. ρ^{-1} will enter the constraint function $\prod z_i$!

The above mapping leads to:

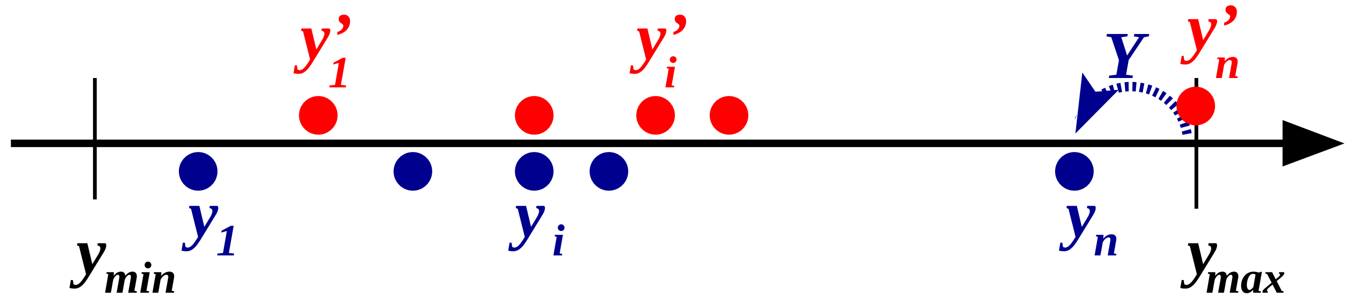
$$x\mathcal{D}_{kk}(t, t_0, x) = e^{-\Phi_k(t,t_0)} \left\{ \delta_{x=1} + \sum_{n=1}^{\infty} \frac{1}{n!} h_k^n \prod_{i=1}^{n} \int_{\rho(t_0-t)}^{\rho(\ln(1-x))} dy_i \; \delta_{x=\prod_{i=1}^n z_i(y_i)} \int_0^1 ds_i \right\}.$$

Linear shift: $y'_i \to y_i = y'_i - Y$



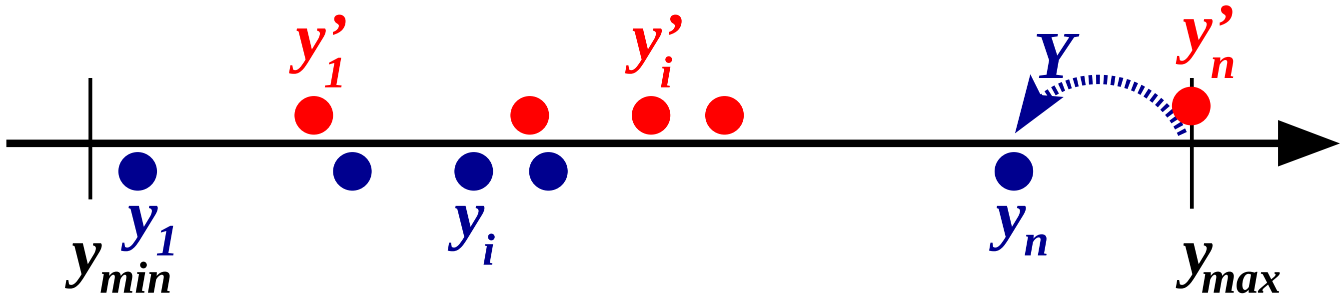
- Begin with y'_i such that one of them $y_n \equiv y_{\max}$

Linear shift: $y_i' \to y_i = y_i' - Y$



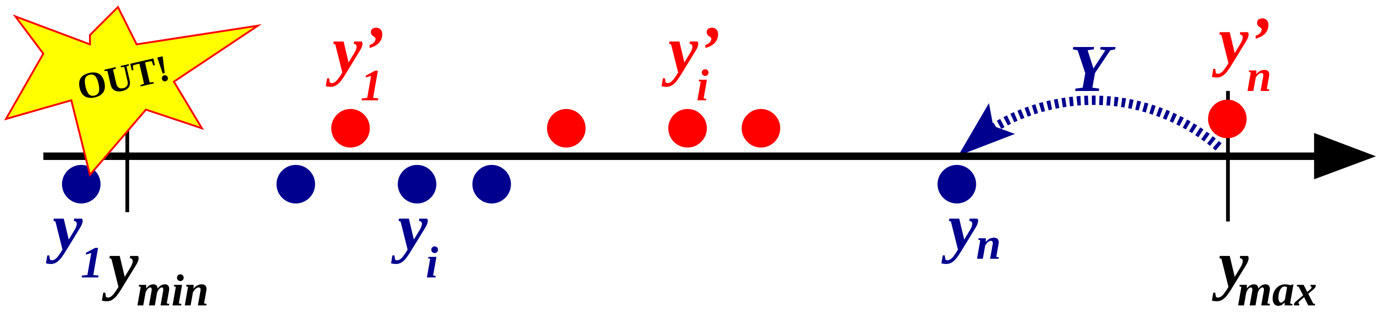
- Begin with y_i' such that one of them $y_n \equiv y_{\max}$
- Shift $y_i' \to y_i$ by Y, where Y solves constraint condition $\prod z_i = x$

Linear shift: $y'_i \to y_i = y'_i - Y(y'_1, y'_2, ..., y'_n)$



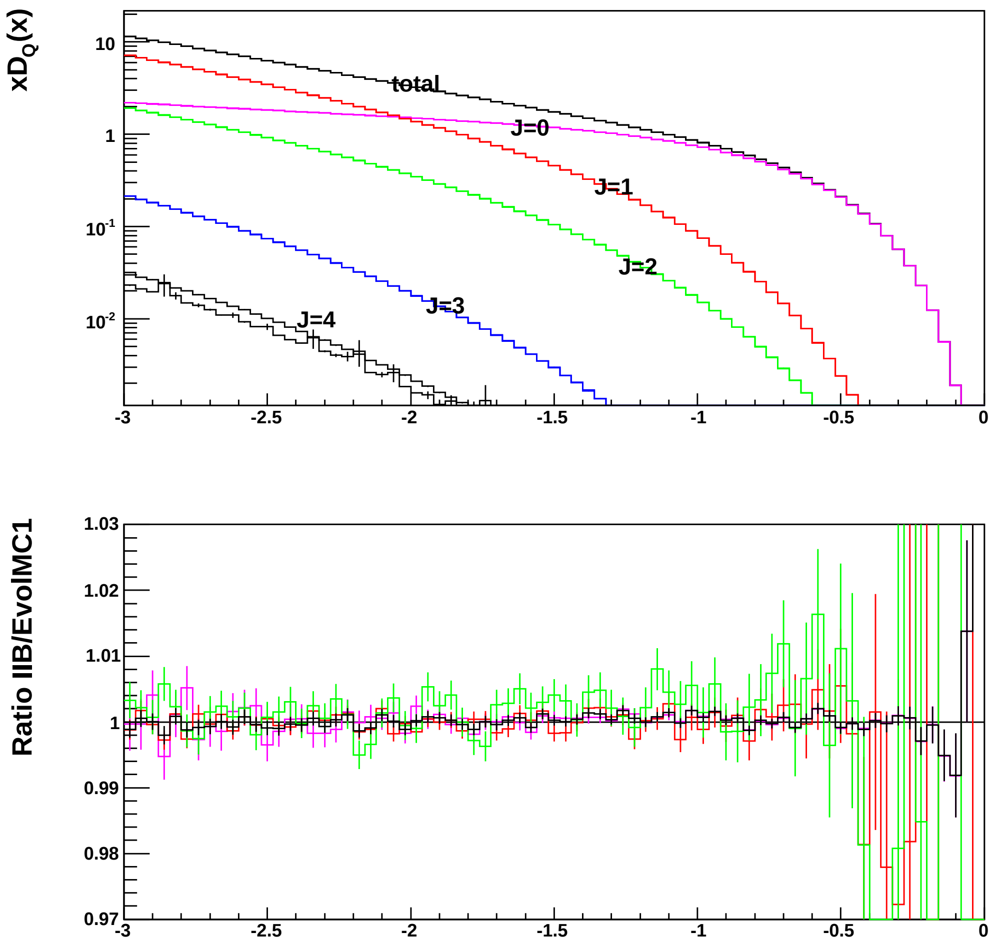
- Begin with y'_i such that one of them $y_n \equiv y_{\max}$
- Shift $y'_i \to y_i$ by Y, where Y solves constraint condition $\prod z_i = x$
- Y is therefore complicated function of all y'_i

Linear shift: $y'_i \to y_i = y'_i - Y(y'_1, y'_2, ..., y'_n)$



- Begin with y'_i such that one of them $y_n \equiv y_{\max}$
- Shift $y'_i \to y_i$ by Y, where Y solves constraint condition $\prod z_i = x$
- Y is therefore complicated function of all y'_i
- Sometimes the smallest y'_i is shifted OUT of the phase space, below IR the limit $y_{\min}$. Such an event gets MC weight $w = 0$

Test CMC/MMC; Evolution 1GeV $\rightarrow$ 1TeV



$J = 0$: $Q \rightarrow Q$

$J = 1$: $G \rightarrow Q$ and any no. of gluon emissions out of Q and G,

$J = 2$: $G \rightarrow Q \rightarrow G \rightarrow Q$, etc.

$J = 3$: $G \rightarrow Q \rightarrow G \rightarrow Q$, etc.

$J = 4$: $Q \rightarrow G \rightarrow Q \rightarrow G \rightarrow Q$, etc. “Total” is the sum of $n = 0, 1, 2, 3, 4$.

Evolution in LL, with $\alpha(q(1-z))$, $\epsilon_{IR} = 1GeV/q$ (HERWIG/CCFM style).

This result was obtained June 2005

Toolbox for mapping of t_i and z_i into phase space (4-momenta)

Emitted particle momenta in terms of lightcone $\pm$ variables and rapidities:

$$k_i = (k_i^+, k_i^-, \vec{k}_{Ti}), \quad \vec{k}_{Ti}^2 = k_i^+ k_i^-, \quad e^{2\eta_i} = \xi_i = \frac{k_i^-}{k_i^+} = \frac{\vec{k}_{Ti}^2}{s k_i^{+2}}$$

Many equivalent parametrization of the same "eikonal phase space element":

$$\frac{d^3 k_i}{2k_i^0}\frac{1}{k_i^- k_i^+} = \frac{dk_i^+ dk_i^- d\varphi_i}{k_i^+ k_i^-} = \frac{d\xi_i dk_i^+ d\varphi_i}{\xi_i k_i^+} = \frac{d\xi_i dz_i d\varphi_i}{\xi_i(1-z_i)} = \frac{dp_{Ti} dz_i d\varphi_i}{p_{Ti}(1-z_i)} = \dots .$$

Identity connecting lightcone variabs. of the emitter z_i with k_i^+ of the emitted particles:

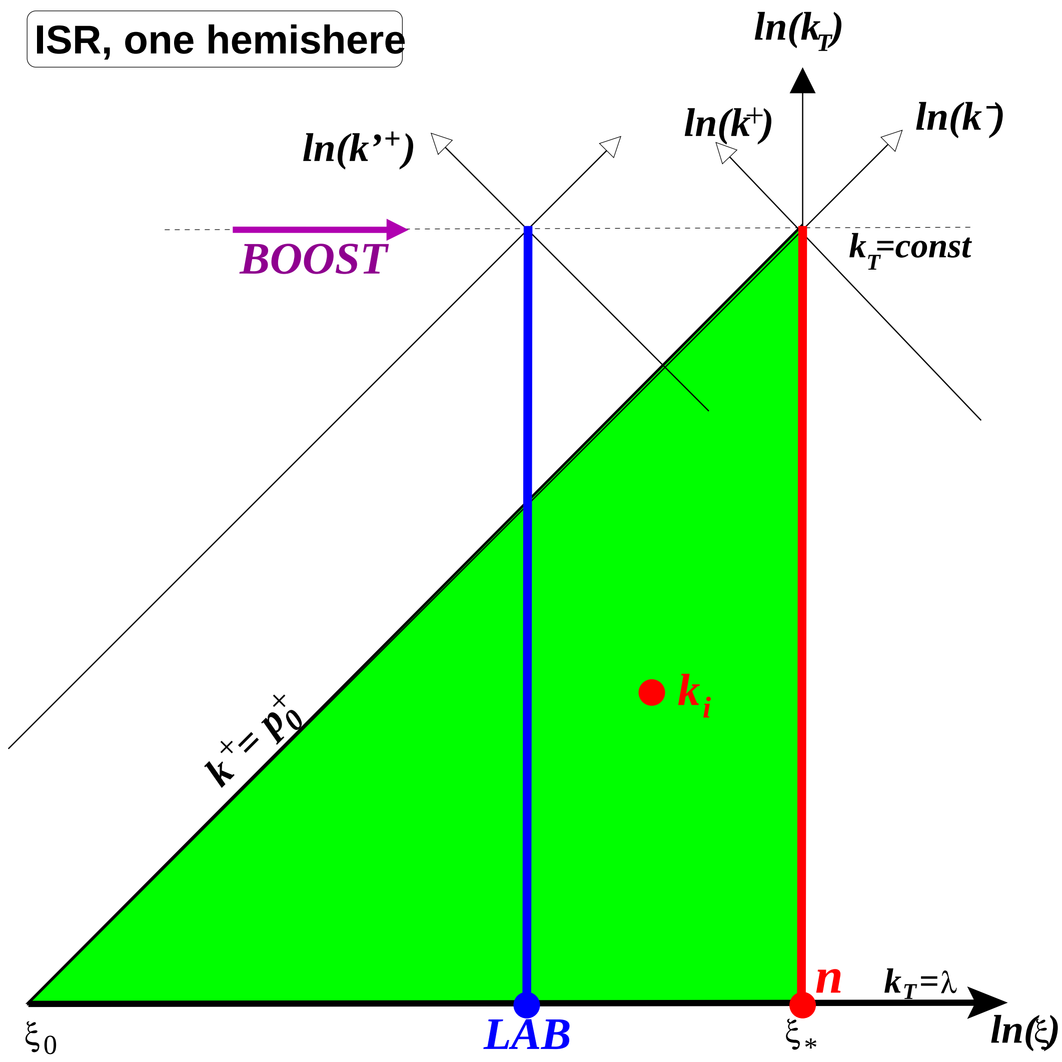
$$\prod_{i=1}^{n} \int_0^{p_0^+} \frac{dk_i^+}{k_i^+} \theta_{\sum_{i=1}^n k_i^+ \leqslant p_0^+} = \int_0^1 \prod_{i=1}^{n} \frac{dz_i}{1-z_i}$$

The IR boundary on k_i^T (alternatively on $x_{i-1} k_i^T$):

$$k_{Ti}^2 = k_i^+ k_i^- = k_i^{+2}\xi_i > \lambda^2, \quad k_i^+ = p_0^+(1-z_i)x_{i-1} > \frac{\lambda}{\sqrt{\xi_i}}, \quad 1-z_i > \frac{\lambda}{p_0^+ x_{i-1}\sqrt{\xi_i}}$$

Last not least, the choice of the evolution time variable: $q_i = p_0^+\sqrt{\xi_i}$,
where $p_0 = (p_0^+, 0, 0, 0)$ is the primary emitter, before the evolution starts.
We chose rapidity as the evolution time!!!! Also equal to maximum k_T of the next emission.

Sudakov plane in (rapidity, k_T) and/or (k^+, k^-)



The phase space is visualized for single emitted particle as a green triangle on the logarithmic plane $(\ln k_T, \ln \xi)$.
It can be also mapped using variables $(\ln k^+, \ln k^-)$ on the same plot.
The boost from one to another frame along p_0 corresponds to trivial horizontal parallel shift (k_T unchanged). Trivial!!!

Master equation for single evolution/hemisphere gluonstrahlung

Master formula for ISR gluonstrahlung out of parton f with the angular ordering:

$$\begin{aligned}
\tilde{D}_f(\xi,x) &= e^{-\Phi_f(\xi,\xi_0)}\delta(1-x) + \\
&+ \sum_{n=0}^{\infty} e^{-\Phi_f(\xi|\xi_n,x)} \left(\prod_{i=1}^{n} \int_{\xi_{i-1}}^{\xi} \frac{d\xi_i}{\xi_i} \int_{\lambda/\sqrt{\xi_i}}^{p_0^+ x_{i-1}} \frac{dk_i^+}{k_i^+} \int \frac{d\varphi_i}{2\pi} \right) \\
&\times \left(\prod_{i=1}^{n} \tilde{\mathbf{P}}_{ff}(k_i,z_i) e^{-\Phi_f(\xi_i|\xi_{i-1},x_{i-1})} \right) \delta_{x=\prod_{i=1}^{n} z_i} \qquad (0) \\
1-z_i &= \frac{k_i^+}{p_0^+ - k_1^+ - k_2^+ \ldots . - k_{i-1}^+} = \frac{k_i^+}{p_0^+ x_{i-1}}, p_0^+ x_{i-1} = p_0^+ - \sum_{j=0}^{i-1} k_j^+,
\end{aligned}$$

where, $\xi_0 = \lambda$, kernel $\tilde{\mathbf{P}}_{ff}(k,z) = z(1-z)\mathbf{P}_{ff}(k,z,x)$ includes α_S

$$\mathbf{P}_{ff}(k,z,x) = \frac{\alpha_S(k)}{\pi} P_{ff}(\xi,z,x) = \frac{\alpha_S(k)}{\pi} \frac{B_{ff}}{z(1-z)} \chi_f(\xi,z),$$

Master equation, cont.

Sudakov formfactor explicitly reads:

$$\begin{aligned}\Phi_f(\xi_i|\xi_{i-1},x_{i-1}) &= \int\limits_{\xi_{i-1}}^{\xi_i} \frac{d\xi'}{\xi'} \int\limits_{\lambda/\sqrt{\xi'}}^{p_0^+ x_{i-1}} \frac{dk'^+}{k'^+} \tilde{\mathbf{P}}_{ff}(k', x_{i-1}) \\ &= \int\limits_{\xi_{i-1}}^{\xi_i} \frac{d\xi'}{\xi'} \int\limits_{0}^{1-\lambda/(p_0^+ x_{i-1}\sqrt{\xi_i})} \frac{dz'}{1-z'} \tilde{\mathbf{P}}_{ff}(z', x_{i-1})\end{aligned}$$

Properties: $\tilde{D}_f(\xi,x)$ obeys an evolution equation:

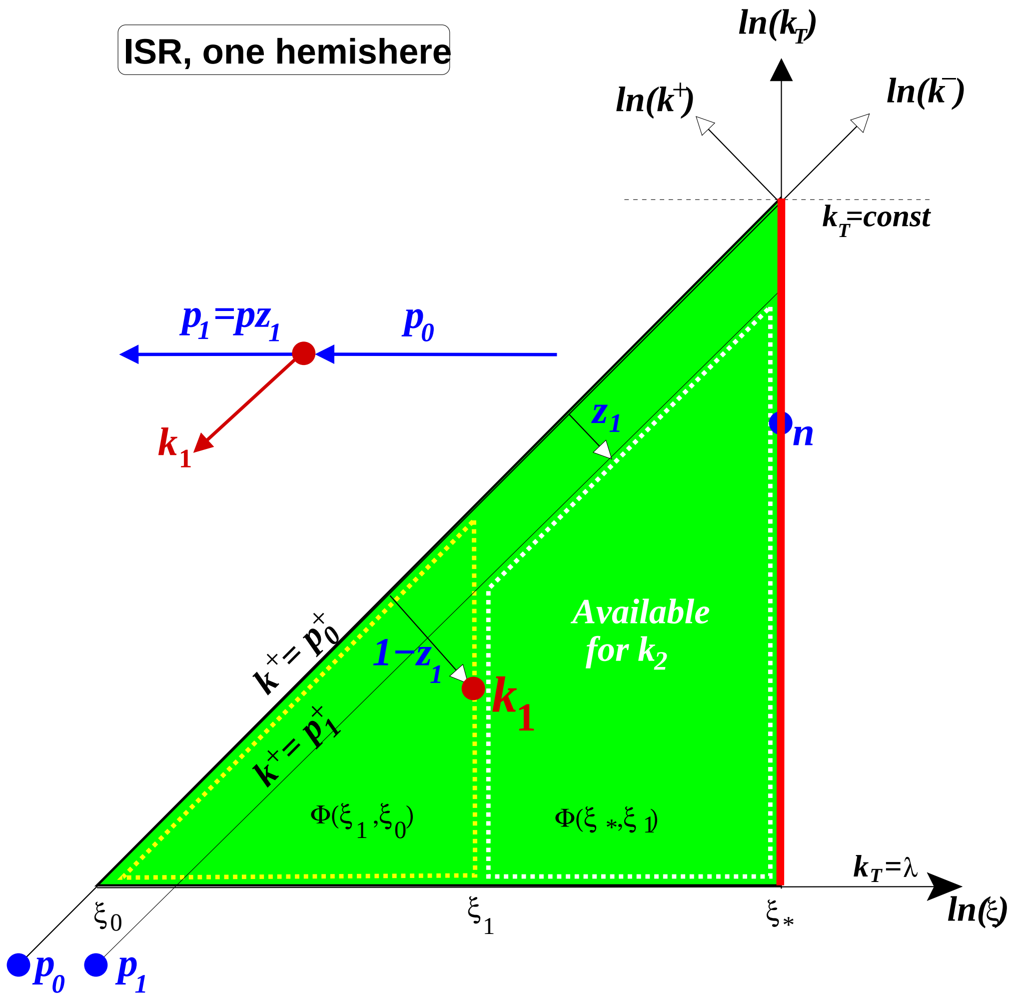
$$\partial_\xi \tilde{D}_f(\xi,x) = \int_0^1 \frac{dz}{1-z} dx P_{ff}(\xi,z,x')\tilde{D}_f(\xi,x')\delta_{x=zx'}$$

The main built in property is the “unitarity”

$$\int_0^1 dx \tilde{D}_f(\xi,x) \equiv 1, \forall\xi,$$

a synonym of the perfect cancellations of the double and single logarithmic (collinear and soft) singularities to infinite order.

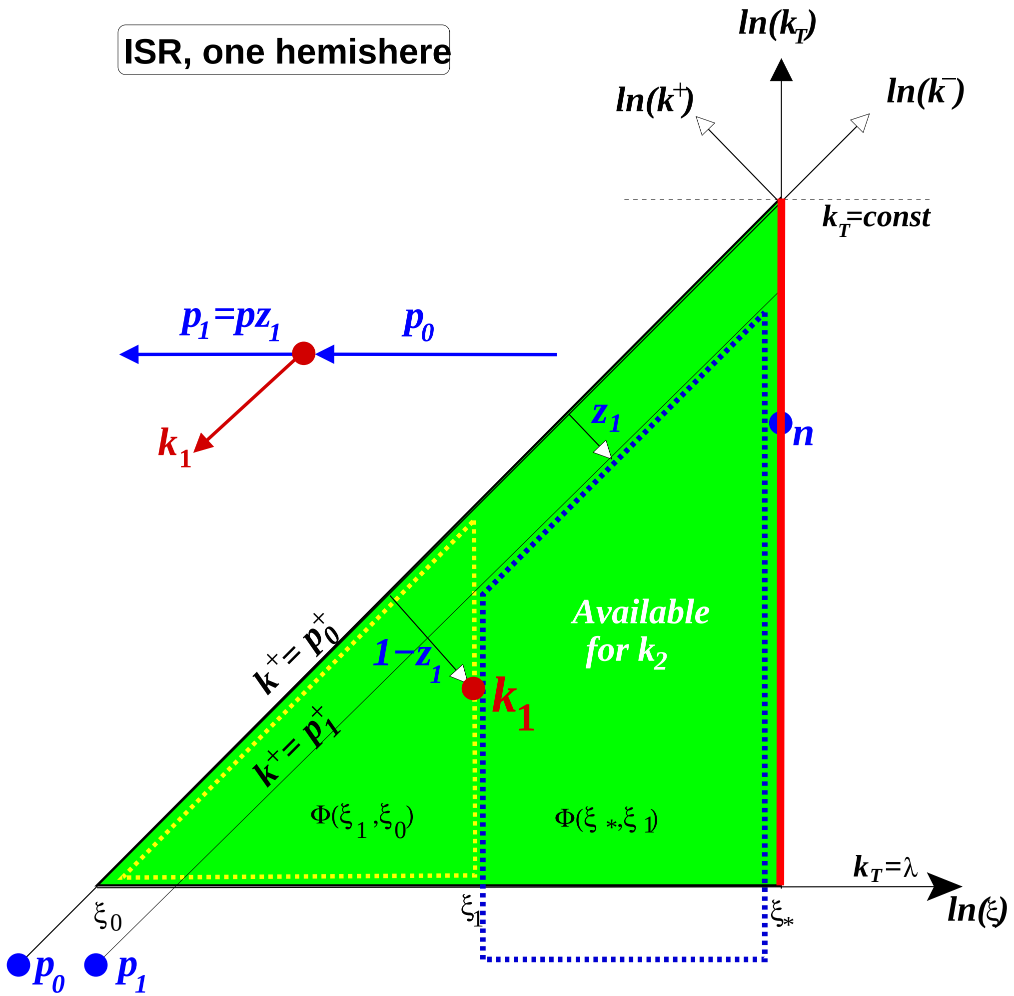
Single emission in a detail, single evolution



Integration domains of $\Phi_f(\xi|\xi_1,x)$ and $\Phi_f(\xi_1|\xi_0,x_0)$are the triangle and trapezoid.

$$\tilde{D}_f(\xi,x)_{n=1} \quad = \quad \int\limits_{\xi_0}^{\xi} \frac{d\xi_1}{\xi_1} \int\limits_{\lambda/\sqrt{\xi_1}}^{p_0^+} \frac{dk_1^+}{k_1^+} \int \frac{d\varphi_1}{2\pi} e^{-\Phi_f(\xi|\xi_1,x)} \tilde{\mathbf{P}}_{ff}(k_1,z_1) e^{-\Phi_f(\xi_1|\xi_0,x_0)} \delta_{x=z_1},$$

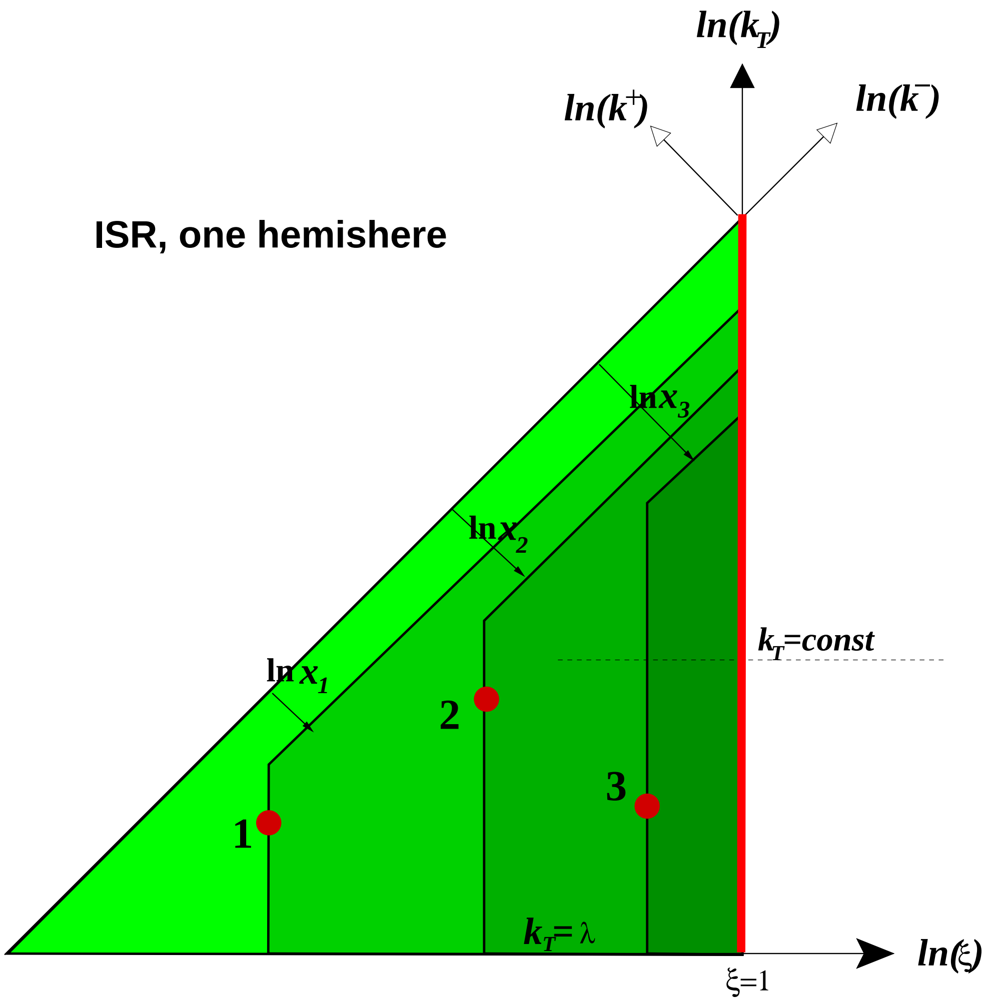
Real emissions in the real CMC



In reality in the present CMC IR boundary is not $k_i^T > \lambda$, but rather $1 - z_i > \frac{\lambda}{p_0^+ \sqrt{\xi_i}}$.

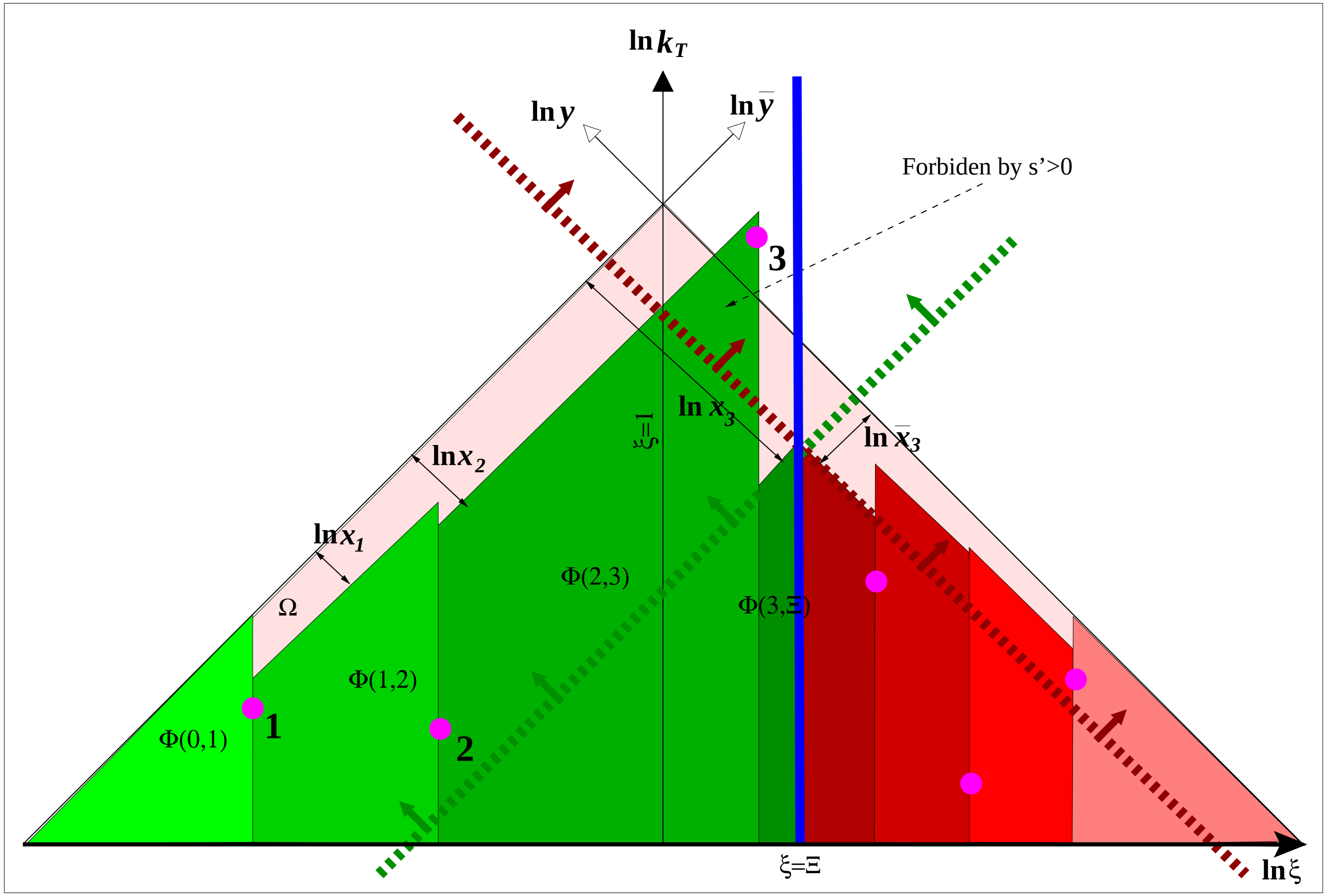
It is depicted above, see blue line defining phase space of the next (2nd) emission.
It will be not a big problem to get $k_i^T > \lambda$ IR cut-off in CMC (one needs to recalculate the formfactor).

3 Real emissions, shrinking phase space



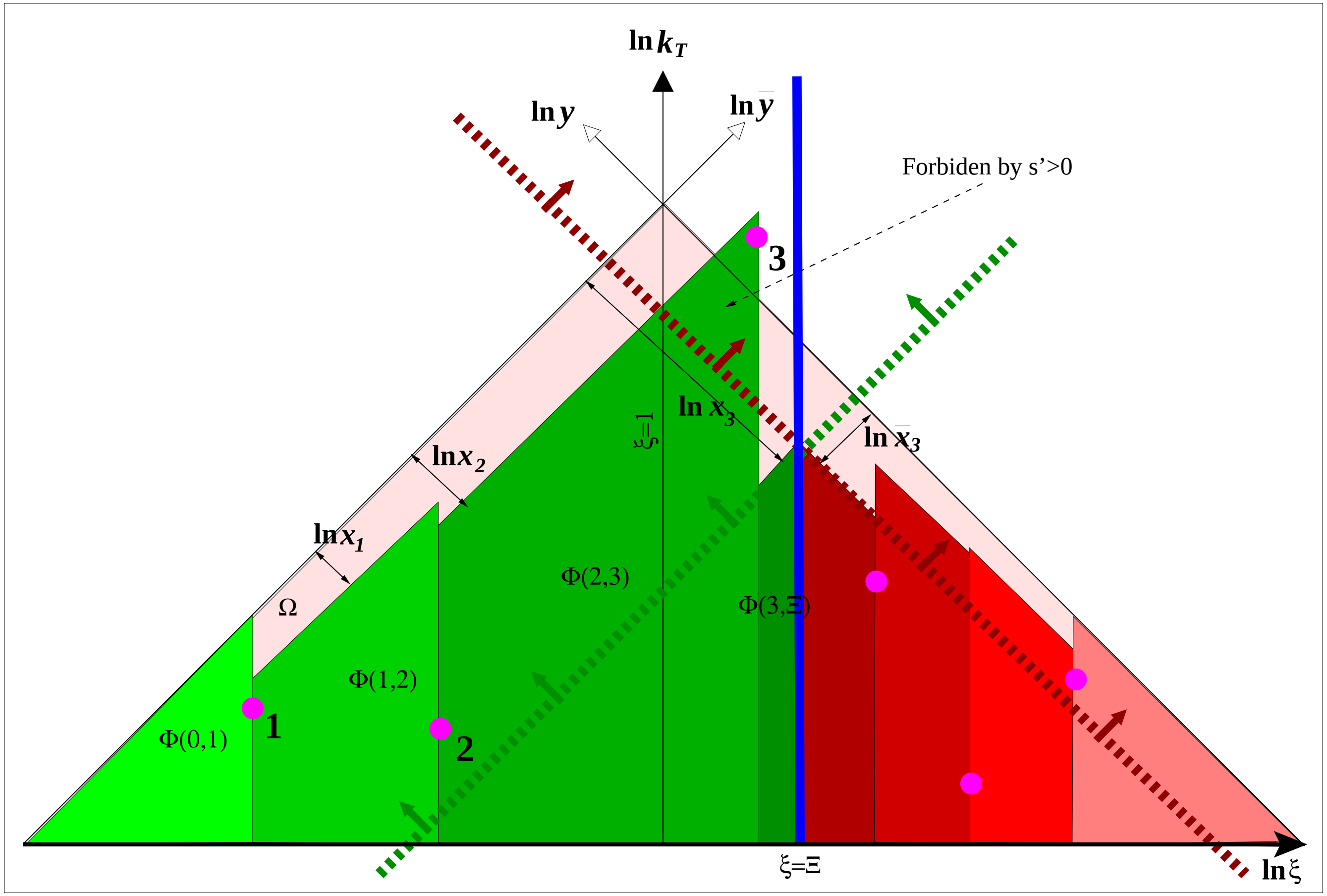
Three ISR emissions ordered in angle. Nested trapezoids indicate (shrinking) phase space for the consecutive real emissions.

Joining smoothly two evolutions in 2 hemispheres



Having CMC for single evolution with the strict maximum rapidity phase space limit (as we do), we may use it twice and join smoothly (without any gap or overlap) the phase space of the emitted gluons, see picture above.
The rapidity of the boundary (blue) line should coincide with rapidity of the W/Z boson, but its position is unimportant, if we are able to implement a correct soft/eikonal limit (as we do).

Joining smoothly two evolutions in 2 hemispheres



The above scenario is already implemented in the prototype Monte Carlo.
There is however one IMPORTANT PROBLEM to be solved:
In the existing CMC for single evolution we put constraint on the $\sum_F p_i^+$ of all gluons in the forward hemisphere and separately on the $\sum_B p_i^-$ in the backward one.
This is not what we need! We have to put the constraint on the effective mass of the W/Z boson which involves also $\sum_F p_i^-$, $\sum_B p_i^+$ and total transverse momenta.
Additional requirement: Total control on the overall normalization.
Can we do it? Yes! We did it, it works! The method is explained in the following.

Rescaling momenta, while keeping track of the normalization

The initial integral with the constraint:

$$I = \int dx dx_{0F} dx_{0B} D(p_0, x_{0F}) D(p_0, x_{0B}) d\rho(k_{iF}, k_{iB}) s\delta\left(sx - (p_{0F} + p_{0B} - K_F - K_B)^2\right)$$

where $K_F = \sum_F k_{iF}$ and $K_B = \sum_B k_{iB}$ are total momenta of **emitted** gluons in the Forw./Backward hemispheres.
$p_{0F} = x_{0F} p_{hF}$, $p_{0B} = x_{0B} p_{hB}$ are 4-mom. of the **primordial** partons at low scale p_0.
Momenta $k_{iF,B}$ are the true phase space variables.
Keeping x, x_{0F}, x_{0B} fixed (external integration), consider the **constrained** subintegral:

$$I'_c(x, x_{0F}, x_{0B}) = \int s\delta\left(sx - (p_{0F} + p_{0B} - K_F - K_B)^2\right) d\rho(k_{iF}, k_{iB})$$

Also introduce explicitly lightcone variables separately for F and B groups of the particles:

$$\begin{aligned} I'_c \quad &= \quad \int dK_F^+ \delta(K_F^+ - \sum_{i\in F} k_{iF}^+) \int dK_B^- \delta(K_B^- - \sum_{i\in B} k_{iB}^-) \\ &\quad s\delta\left(sx - (p_{0F} + p_{0B} - K_F - K_B)^2\right) d\rho(k_{iF}, k_{iB}) \end{aligned}$$

Simplified constraint

Existing CMC is able to constrain on plus-variables in Forward hemispher and on minus-variables in Backward hemisphere.
Rewrite/simplify our basic constraint keeping this in mind:

$$
\begin{aligned}
s' = sx \quad &\rightarrow \quad 2p_{0F}\cdot p_{0B} - 2p_{0F}\cdot K_B - 2p_{0B}\cdot K_F + 2K_F\cdot K_B \\
&\rightarrow \quad 2p^0_{0F}p^0_{0B} + 2p^0_{0F}K^-_B + 2p^0_{0B}K^+_F + 2K^+_F\cdot K^-_B \\
&= \quad 2p^0_{0F}p^0_{0B}(1-(1-Z_B)-(1-Z_F)+(1-Z_B)(1-Z_F)) \\
&= \quad 2p^0_{0F}p^0_{0B}Z_FZ_B = s(x_{0F}x_{0B})Z_FZ_B,
\end{aligned}
$$

where we defined $K^-_B = p^0_{0B}(1-Z_B)$ and $K^+_F = p^0_{0F}(1-Z_F)$ conventionally.
Next we introduce new δ with thesimplified constraint, using auxiliary variable Y:

$$
\begin{aligned}
I_c \quad = \quad & \int dY \int dK^+_F\delta(K^+_F - \sum_{i\in F}k^+_{iF}) \int dK^-_B\delta(K^-_B - \sum_{i\in B}k^-_{iB}) \\
& \delta(sx - 2p^0_{0F}p^0_{0B} + 2p^0_{0F}K^-_B Y^{-1} + 2p^0_{0B}\cdot K^+_F Y^{-1} - 2K^+_F\cdot K^-_B Y^{-2}) \\
& Y^{-1}[2p^0_{0F}K^-_B Y^{-1} + 2p^0_{0B}K^+_F Y^{-1} - 2K^+_F\cdot K^-_B 2Y^{-2}] \\
& s\delta\left(sx - (p_{0F}+p_{0B}-K_F-K_B)^2\right) d\rho(p_{iF},p_{iB})
\end{aligned}
$$

Trading true constraint for simplified one

Rescale all emitted momenta: $k_{iF} = Y\hat{k}_{iF}$ and $k_{iB} = Y\hat{k}_{iB}$, $K_F = Y\hat{K}_F$ and $K_B = Y\hat{K}_B$. Assume $d\rho(k_{iF}, k_{iB}) = d\rho(\hat{k}_{iF}, \hat{k}_{iB})$. It is a good (eikonal) approximation. If not true, then extra MC weight will correct for that.

$$
\begin{aligned}
I_c \quad = \quad & \int dY \int d\hat{K}^+_F \delta(\hat{K}^+_F - \sum_{i\in F} \hat{k}^+_{iF}) \int d\hat{K}^-_B \delta(\hat{K}^-_B - \sum_{i\in B} \hat{k}^-_{iB}) \\
& \delta(sx - 2p^0_{0F} p^0_{0B} + 2p^0_{0F} \hat{K}^-_B + 2p^0_{0B} \hat{K}^+_F - 2\hat{K}^+_F \cdot \hat{K}^-_B) \\
& Y^{-1} [2p^0_{0F} \hat{K}^-_B + 2p^0_{0B} \hat{K}^+_F - 4\hat{K}^+_F \cdot \hat{K}^-_B] \\
& s\delta\left(sx - (p_{0F} + p_{0B} - Y\hat{K}_F - Y\hat{K}_B)^2\right) d\rho(\hat{k}_{iF}, \hat{k}_{iB})
\end{aligned}
$$

Y is now “transferred” to old basic constraint, which is next eliminated by Y-integration:

$$
\begin{aligned}
I_c \quad = \quad & \int d\hat{K}^+_F \delta(\hat{K}^+_F - \sum_{i\in F} \hat{k}^+_{iF}) \int d\hat{K}^-_B \delta(\hat{K}^-_B - \sum_{i\in B} \hat{k}^-_{iB}) \\
& \delta(sx - 2p^0_{0F} p^0_{0B} + 2p^0_{0F} \hat{K}^-_B + 2p^0_{0B} \hat{K}^+_F - 2\hat{K}^+_F \cdot \hat{K}^-_B) \\
& Y_0^{-1} [2p^0_{0F} \hat{K}^-_B + 2p^0_{0B} \hat{K}^+_F - 4\hat{K}^+_F \cdot \hat{K}^-_B] s\mathfrak{J}(Y_0)^{-1} d\rho(\hat{k}_{iF}, \hat{k}_{iB}),
\end{aligned}
$$

where Y_0 is solution of the 2nd order equation $sx = (p_{0F} + p_{0B} - Y\hat{K}_F - Y\hat{K}_B)^2$ and $\mathfrak{J}(Y_0) = 2(p_{0F} + p_{0B} - Y_0\hat{K}_F - Y_0\hat{K}_B) \cdot (\hat{K}_F + \hat{K}_B)$ is important Jacobian factor.

MC distributions and weights

Defining $K^{+}_{F,B} = p^{0}_{0F,B}(1 - Z_{F,B})$ and $s_0 = 2p^{0}_{0F}p^{0}_{0B} = sx_{0F}x_{0B}$, we continue "business as usual" in the two "weakly coupled" hemispheres:

$$I_c = \int dZ_F \delta(1 - \hat{Z}_F - \sum x^{+}_{iF}) d\rho(\hat{k}_{iF}) \int dZ_B \delta(1 - \hat{Z}_B - \sum x^{-}_{iB}) d\rho(\hat{k}_{iB})$$
$$s\delta(sx - s_0 \hat{Z}_F \hat{Z}_B) Y_0^{-1} \mathfrak{N}(Z_F, Z_B),$$

where all Jacobians are combined into single factor $\mathfrak{N}(Z_F, Z_B)$.
For the MC purpose it is useful to know its approximate form (for the weight stabilization):

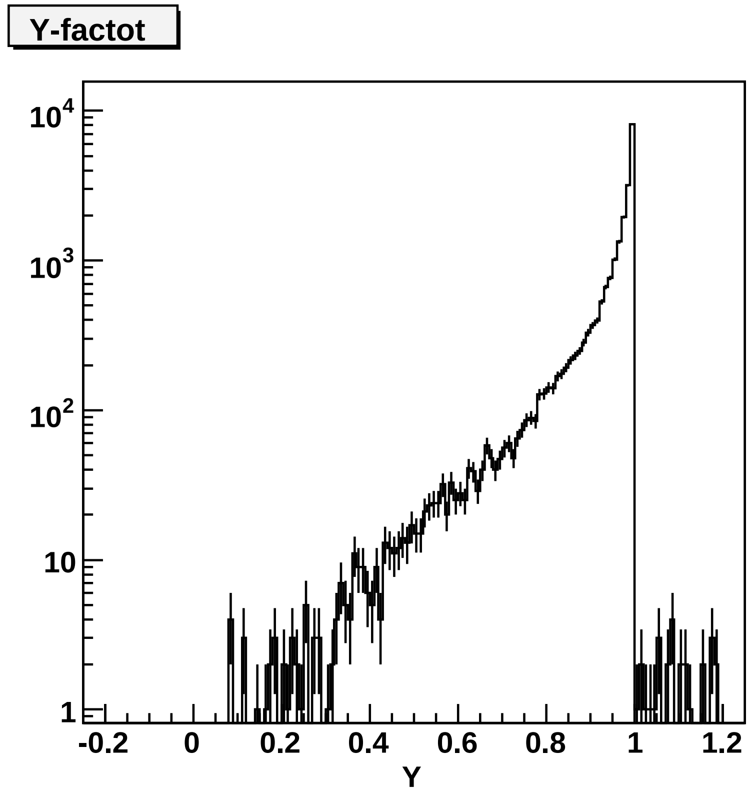
$$\overline{\mathfrak{N}}(Z_F, Z_B) = \frac{\hat{Z}_F + \hat{Z}_B - 2\hat{Z}_F\hat{Z}_B}{[(\hat{Z}_F - \hat{Z}_B)^2 + 4(1-\hat{Z}_F)(1-\hat{Z}_F)\hat{Z}_F\hat{Z}_B]^{1/2}}$$

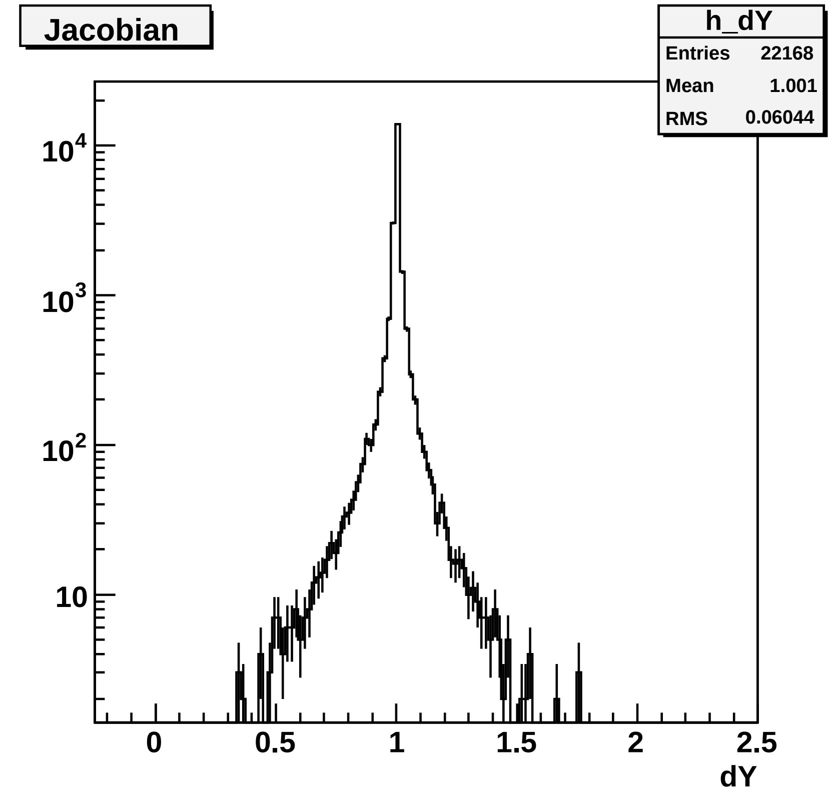
The above is treated by the Foam and the correcting MC weight includes only

$$W_{\mathfrak{N}} = \frac{s_1[(\hat{Z}_F - \hat{Z}_B)^2 + 4(1-\hat{Z}_F)(1-\hat{Z}_F)\hat{Z}_F\hat{Z}_B]^{1/2}}{\mathfrak{J}(Y_0, \hat{K}_F, \hat{K}_B)},$$

which turns out to be friendly, strongly peaked at 1.

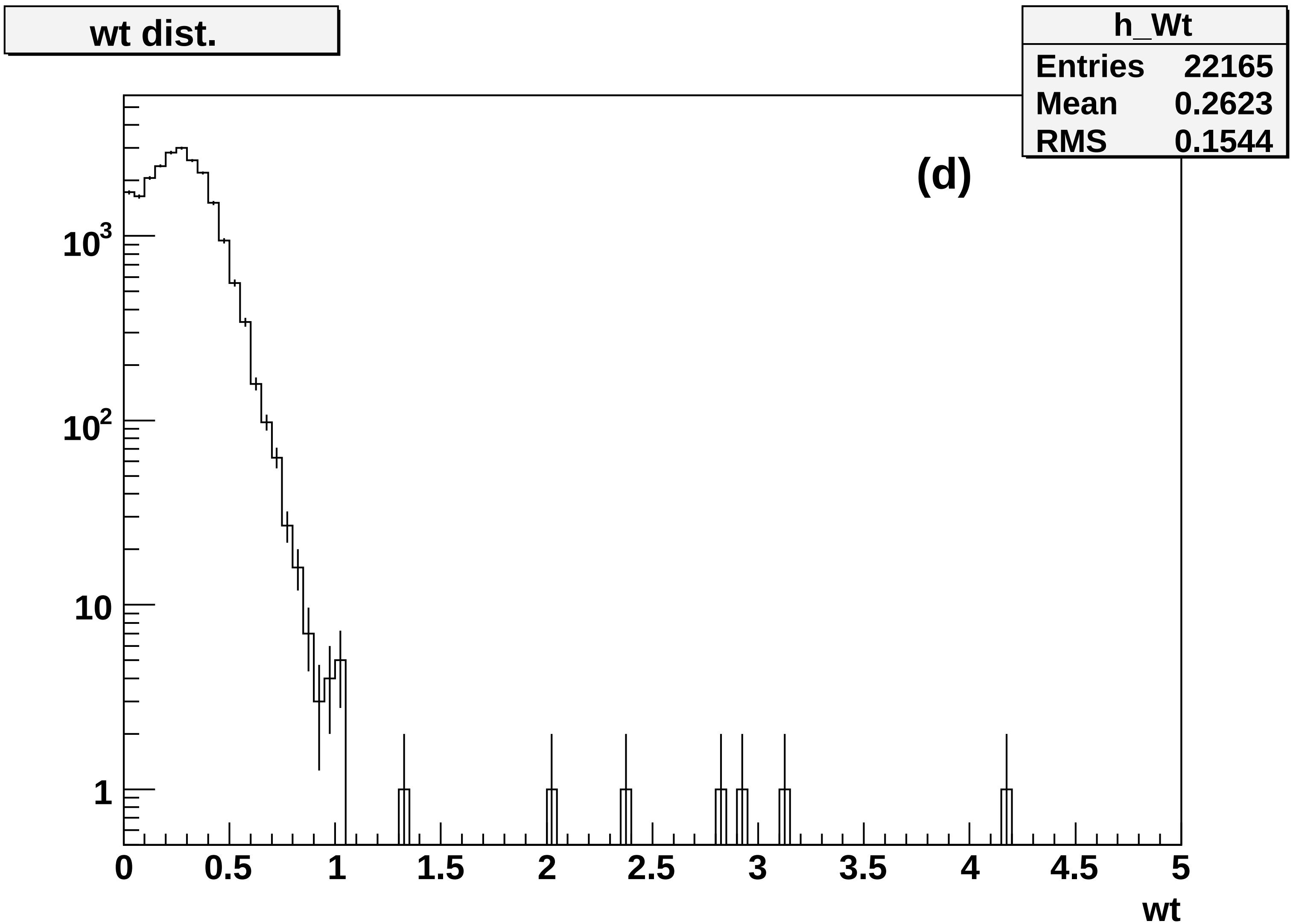
MC distributions and weights, numerical results





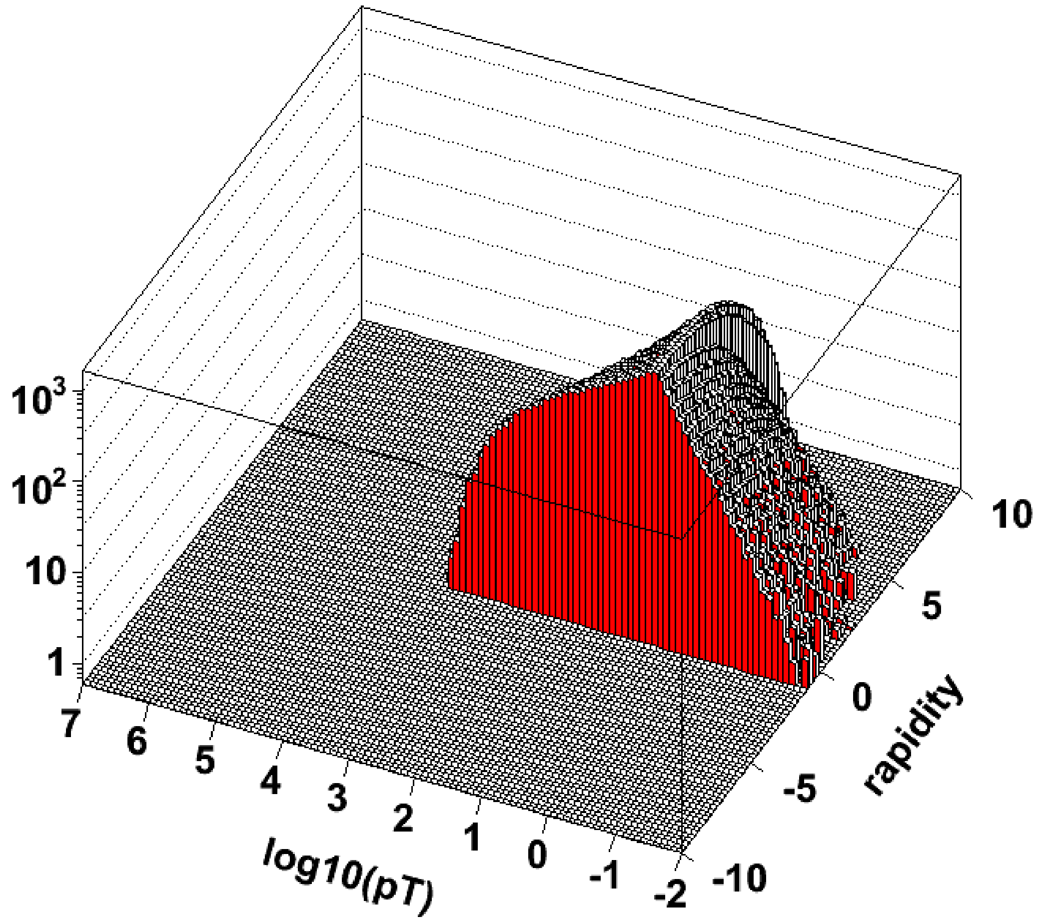
The above plots show the distribution of the rescaling factor Y (left) and of the component weight $W_{\mathfrak{M}}$ (right). The total weight is on the next slide.

MC distributions and weights, numerical results



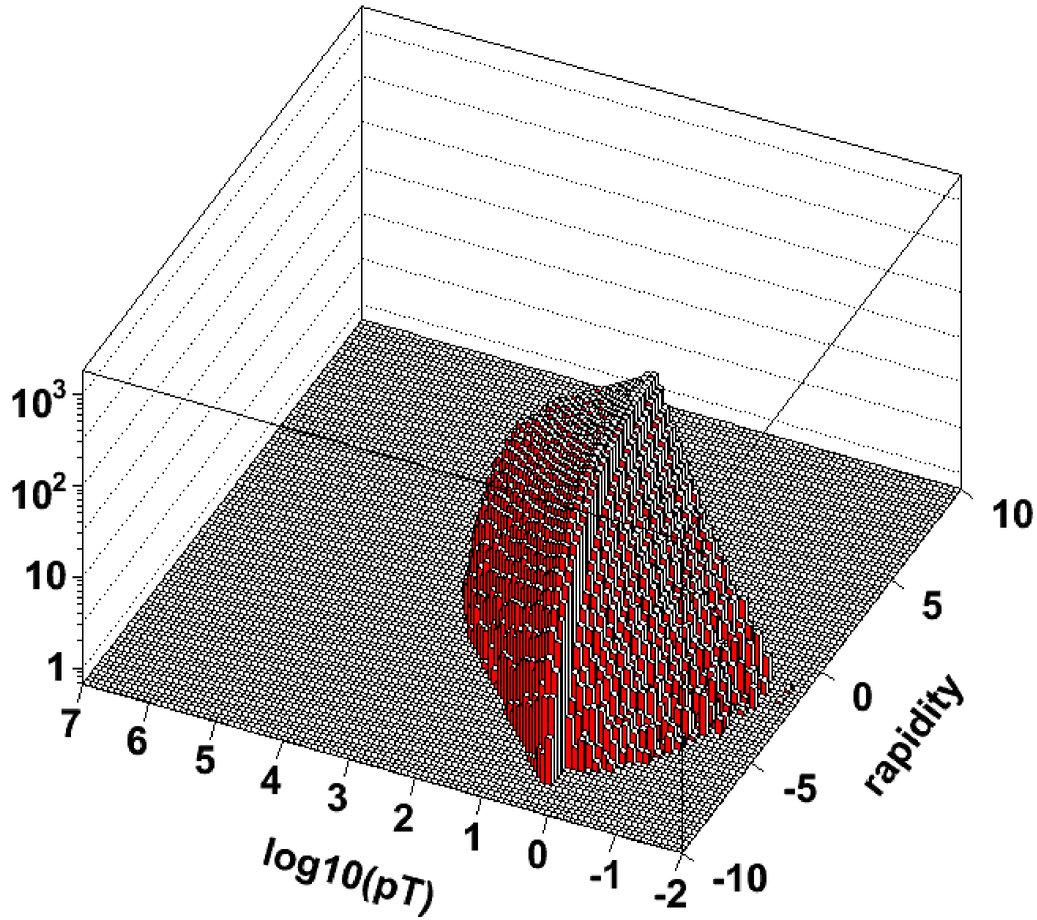
The distribution of the total MC weight looks rather good. The tail of the high weights looks insignificant. It will be examined anyway.

Full coverage of the phase space (emitted gluons)



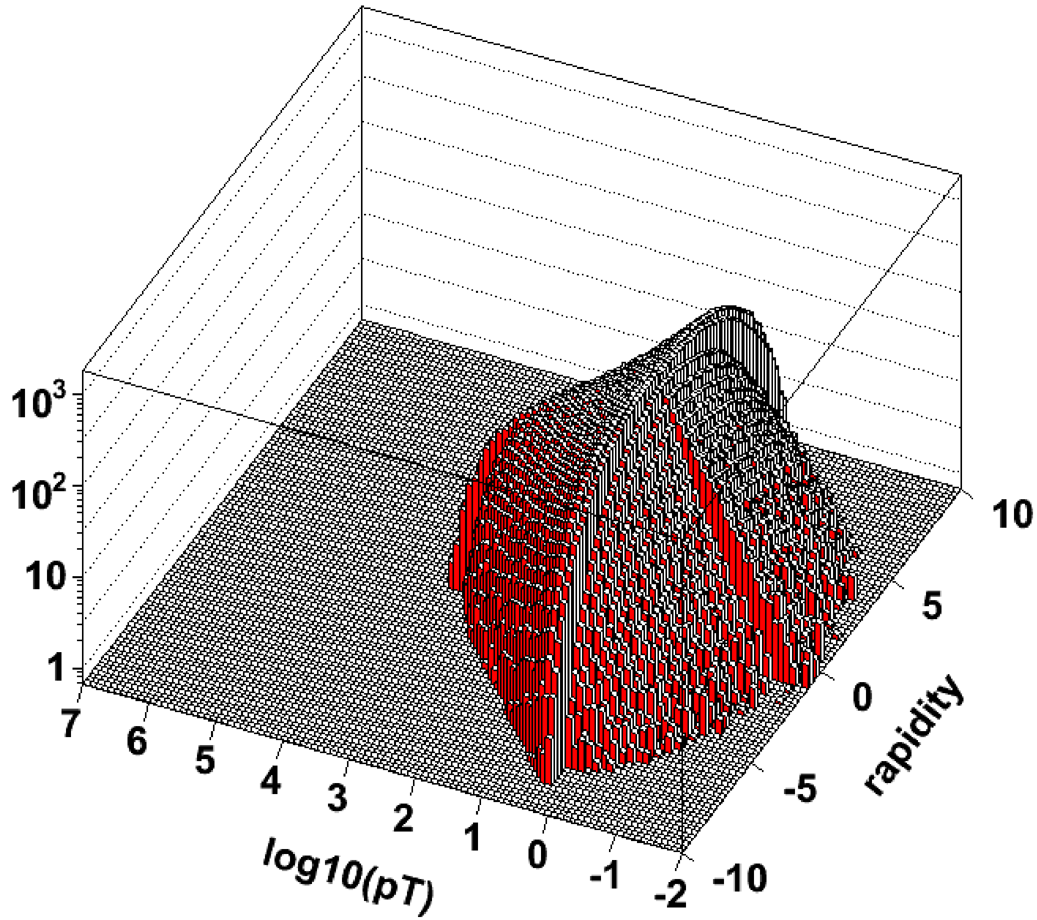
- Full coverage of the rapidity-pT space of emitted gluons, Forward hemisphere

Full coverage of the phase space (emitted gluons)



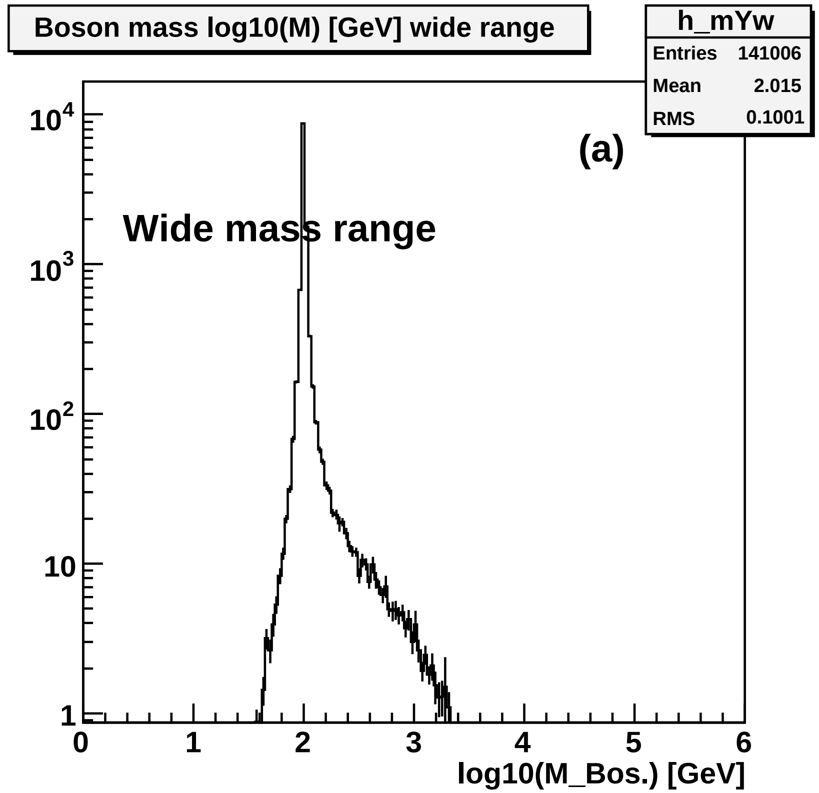
- Full coverage of the rapidity-pT space of emitted gluons, Forward hemisphere
- Full coverage of the rapidity-pT space, Backward hemisphere

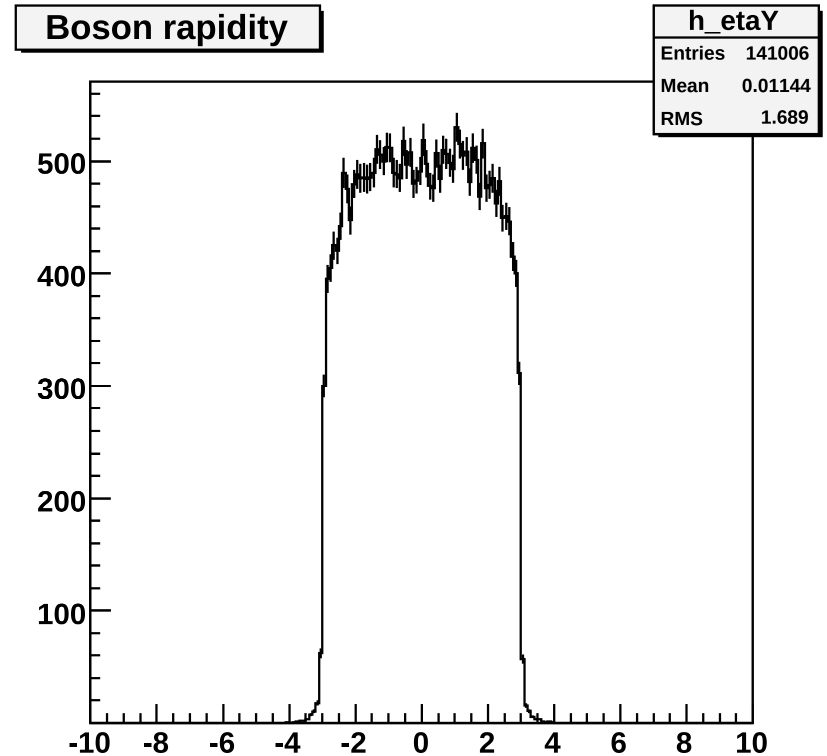
Full coverage of the phase space (emitted gluons)



- Full coverage of the rapidity-pT space of emitted gluons, Forward hemisphere
- Full coverage of the rapidity-pT space, Backward hemisphere
- Perfect matching of 2 hemispheres, no overlap, no gaps..

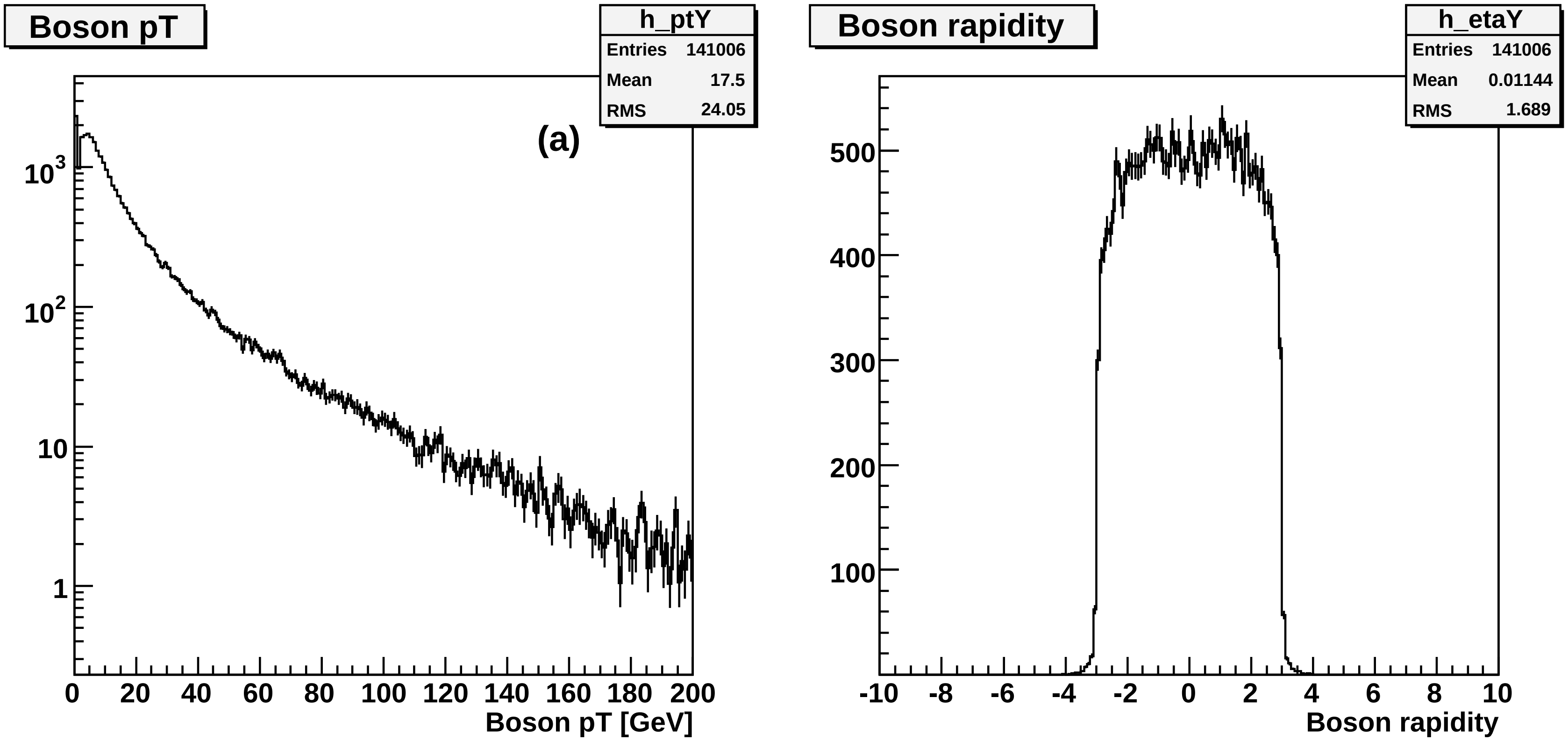
EW boson mass and rapitity distributions





The previous examples were for Z' boson of mass 1TeV and width 100GeV.
Here we show mass and rapidity distribution of the EW boson (mass 100GeV). Matrix element is maximally simplified (only Breit-Wigner).

EW boson transverse momentum and rapitity distributions



Transverse momentum and rapidity distribution of the EW boson (mass 100GeV). Matrix element is maximally simplified (only Breit-Wigner).

Summary and outlook

- It was demonstrated that joining two single evolutions into one Initial State radiation Monte Carlo with the constraint on the true W/Z boson mass is possible, while keeping perfect control on the overall normalization.
- Immediate plans:
  - More numerical tests against MMC$_F \otimes$MMC$_B$
  - Inclusion of the Quark-Gluon transitions
  - Constructing variant with IR cut $k_I^T > \lambda$ and $\alpha_S(k^T)$
- Other plans:
  - Constructing variant of the same kind of the MC for DIS, fitting F_2
  - Inclusion of NLO into hard process (coeff. funct.)
  - Inclusion of NLO into MC evolution at the 4-momenta level.