Direct photon production in KaTie

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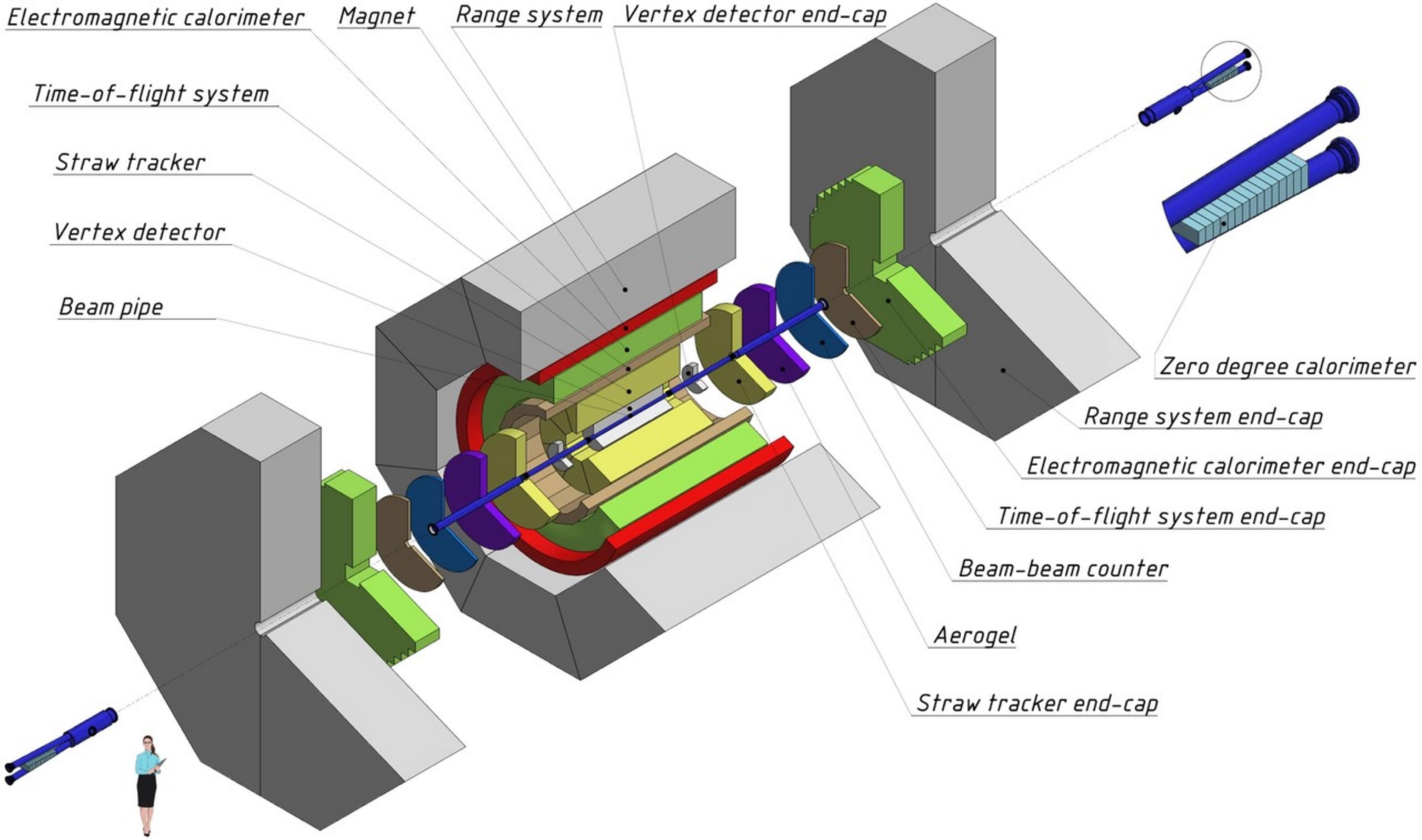
Quantum chromodynamics

$$L(x) = -\frac{1}{4}G^a_{\mu\nu}(x)G^a_{\mu\nu}(x) + \sum_f \bar{q}_f(x)(i\gamma^\mu D_\mu - m_q)q_f(x),$$

$$G^a_{\mu\nu}(x) = \partial_\mu A^a_\nu(x) - \partial_\nu A^a_\mu(x) + g_s f^{abc} A^b_\mu(x) A^c_\nu(x)\,.$$

Spin Physics Detector

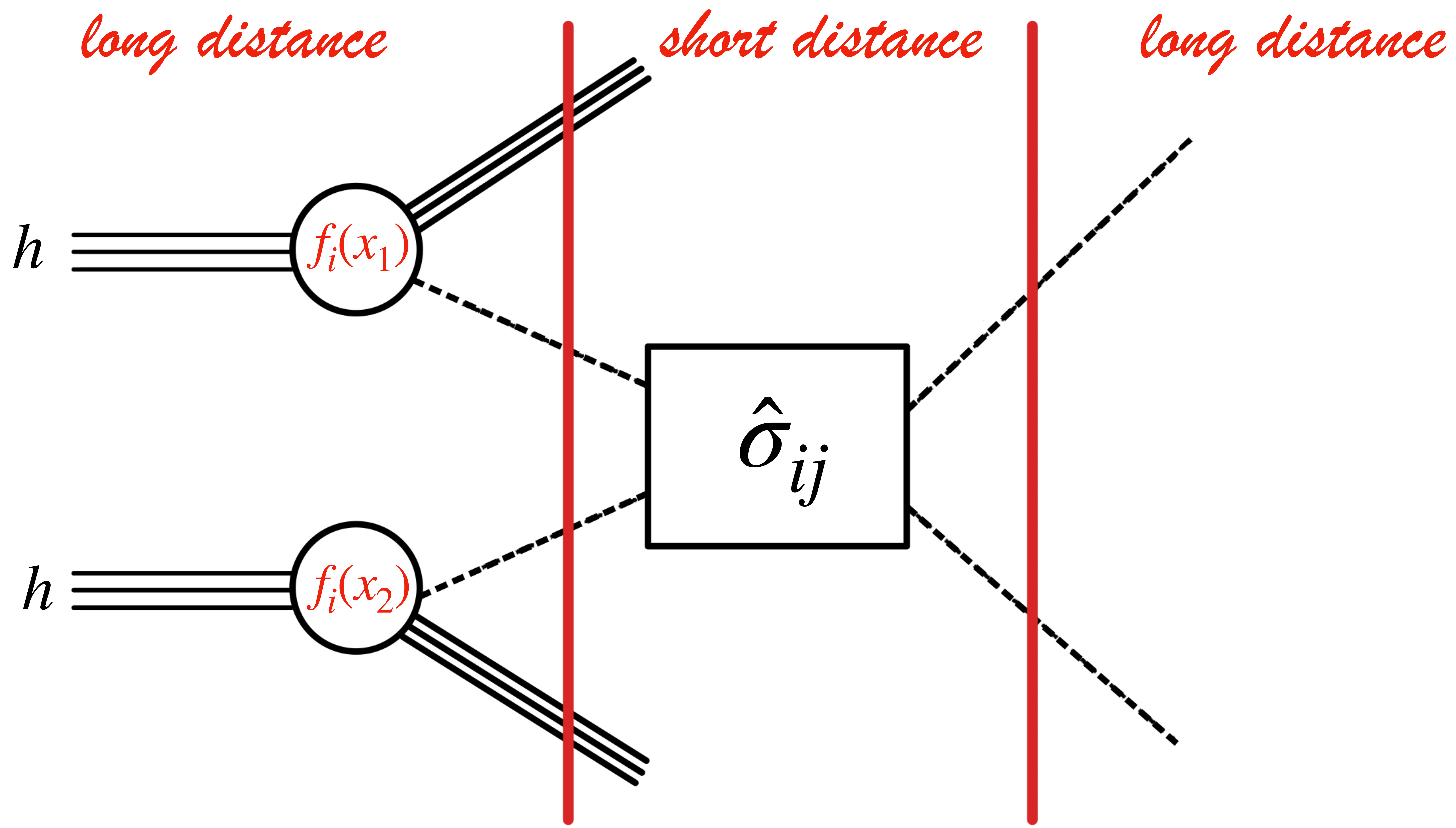


Direct photons

- Direct photons were predicted to exist by C.O. Escobar in 1975[Escobar, 1975].

- First observation of direct photons was made by the R412 group at the Intersecting Storage Rings at CERN in 1976 [Darriulat P. et al., 1976].

Factorization of Hard Processes in QCD



$$\sigma_{hh\to XY} = \sum_{i,j=q,\bar{q},g} \int_0^1 dx_1\ f_i(x_1,\mu^2) \int_0^1 dx_2\ f_j(x_2,\mu^2) \times \hat{\sigma}(ij \to ab) \times D_{ab\to X}$$

Collinear parton model

$$d\sigma(p\ p \to k\ X) = \sum_{a,b} \int dx_1 f_a(x_1, \mu^2) \int dx_2 f_b(x_2, \mu^2) d\hat{\sigma}(a + b \to k),$$

$$q^\mu = xP^\mu, \quad q_T = 0, \quad q^2 = 0.$$

Parton distribution functions

$$\int_0^1 (f_u(x) - f_{\bar{u}}(x))dx = 2;$$

$$\int_0^1 (f_d(x) - f_{\bar{d}}(x))dx = 1;$$

$$\int_0^1 (f_s(x) - f_{\bar{s}}(x))dx = 0;$$

$$\int_0^1 dx\ x(f_u(x) + f_{\bar{u}}(x) + f_d(x) + f_{\bar{d}}(x) + f_s(x) + f_{\bar{s}}(x) + f_g(x)) = 1.$$

DGLAP evolution equations

$$\frac{\alpha_s(Q)}{\pi},$$

$$\frac{d}{d\ln\mu^2} f_g(x,\mu^2) = \frac{\alpha_s(\mu^2)}{\pi}\int_x^1 \frac{dz}{z}\left\{P_{g\leftarrow q}(z)\sum_f\left[f_q\left(\frac{x}{z},\mu^2\right) + f_{\bar{q}}\left(\frac{x}{z},\mu^2\right)\right] + P_{g\leftarrow g}(z) f_g\left(\frac{x}{z},\mu^2\right)\right\},$$

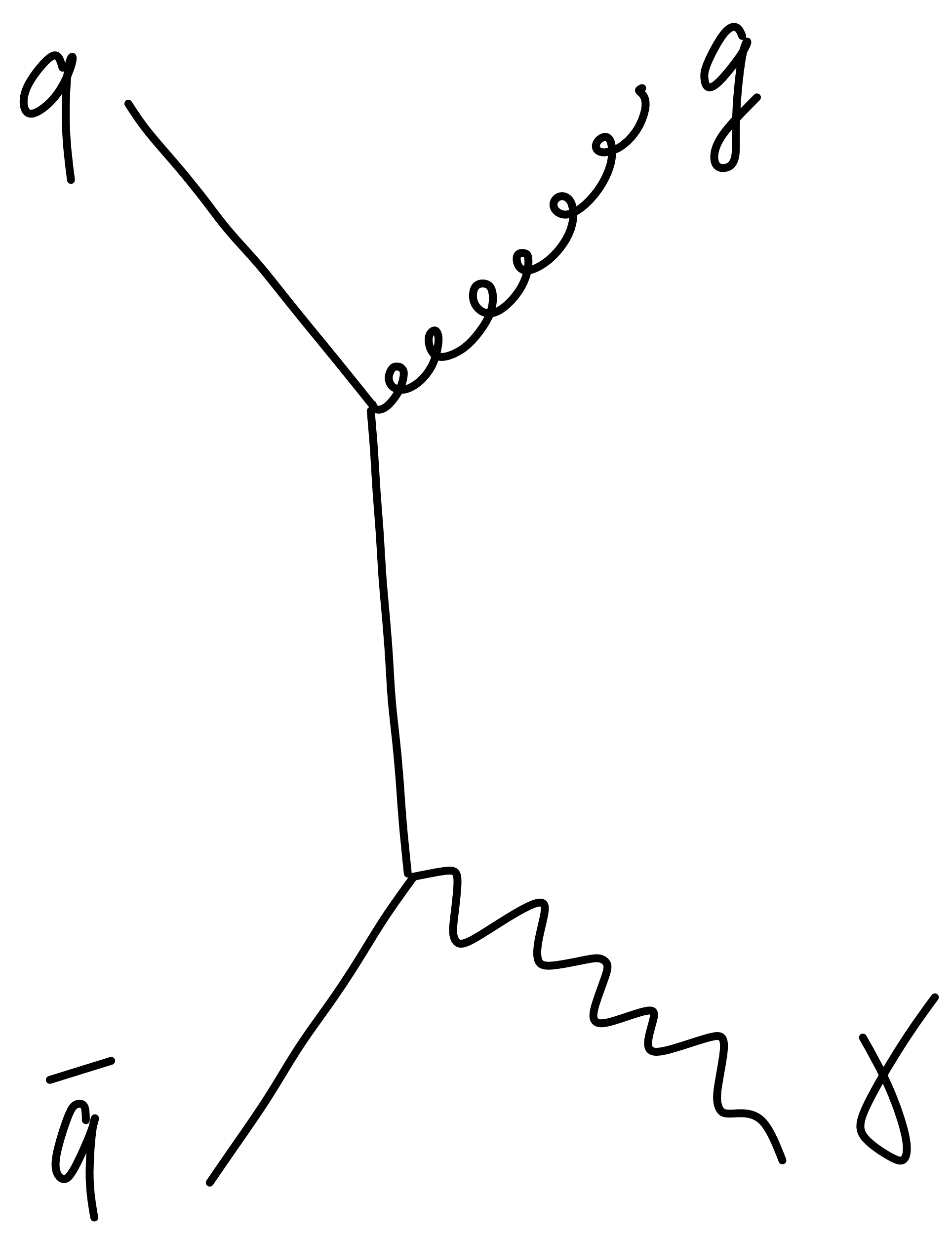
$$\frac{d}{d\ln\mu^2} f_q(x,\mu^2) = \frac{\alpha_s(\mu^2)}{\pi}\int_x^1 \frac{dz}{z}\left\{P_{q\leftarrow q}(z) f_q\left(\frac{x}{z},\mu^2\right) + P_{q\leftarrow g}(z) f_g\left(\frac{x}{z},\mu^2\right)\right\},$$

$$\frac{d}{d\ln\mu^2} f_{\bar{q}}(x,\mu^2) = \frac{\alpha_s(\mu^2)}{\pi}\int_x^1 \frac{dz}{z}\left\{P_{q\leftarrow q}(z) f_{\bar{q}}\left(\frac{x}{z},\mu^2\right) + P_{q\leftarrow g}(z) f_g\left(\frac{x}{z},\mu^2\right)\right\}.$$

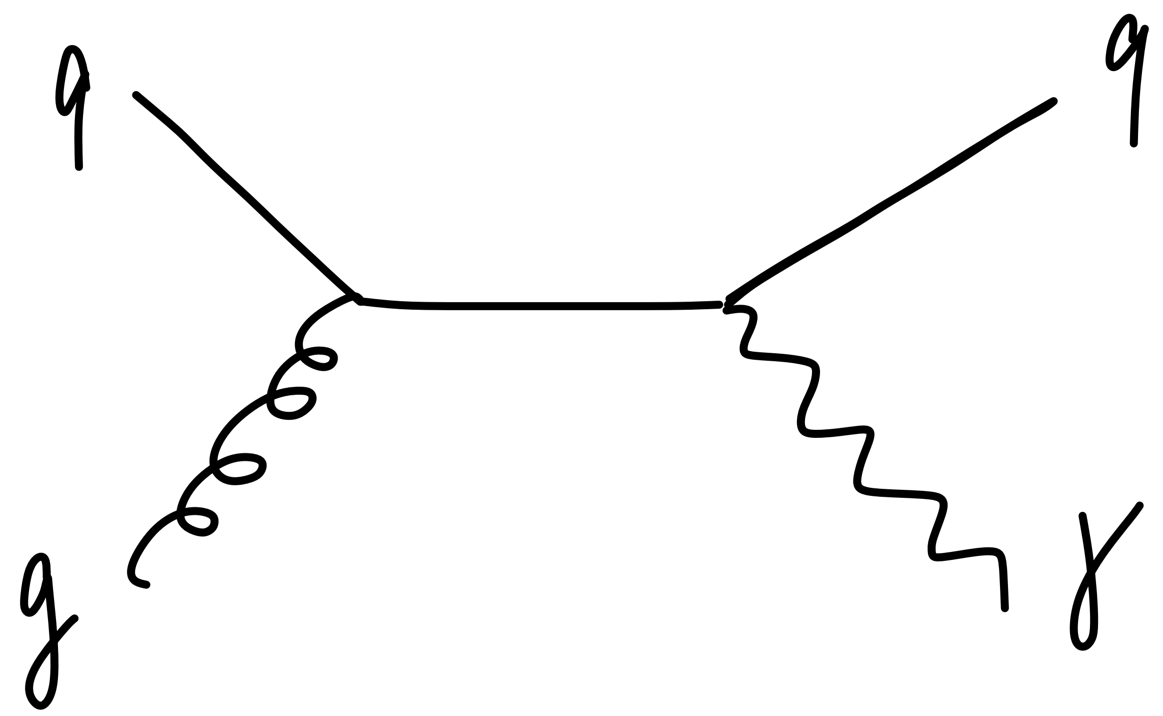
Results

Motivation

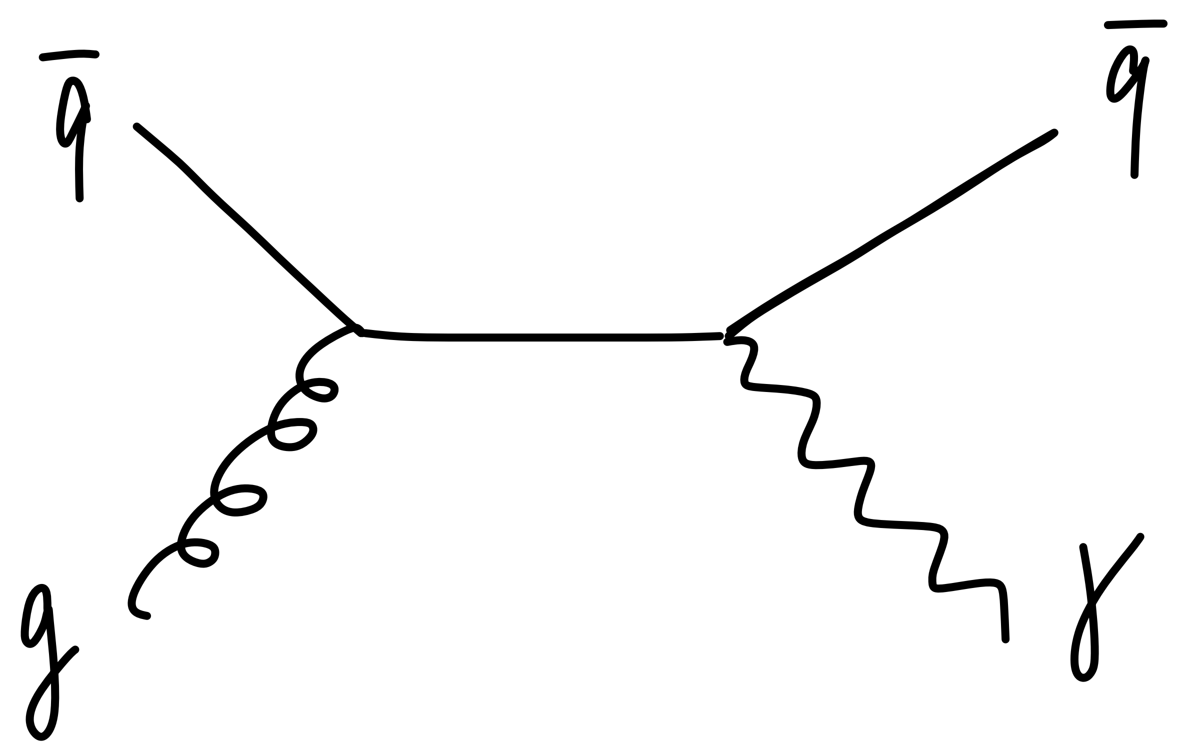
$q + \bar{q} \rightarrow g + \gamma$



$q + g \rightarrow q + \gamma$

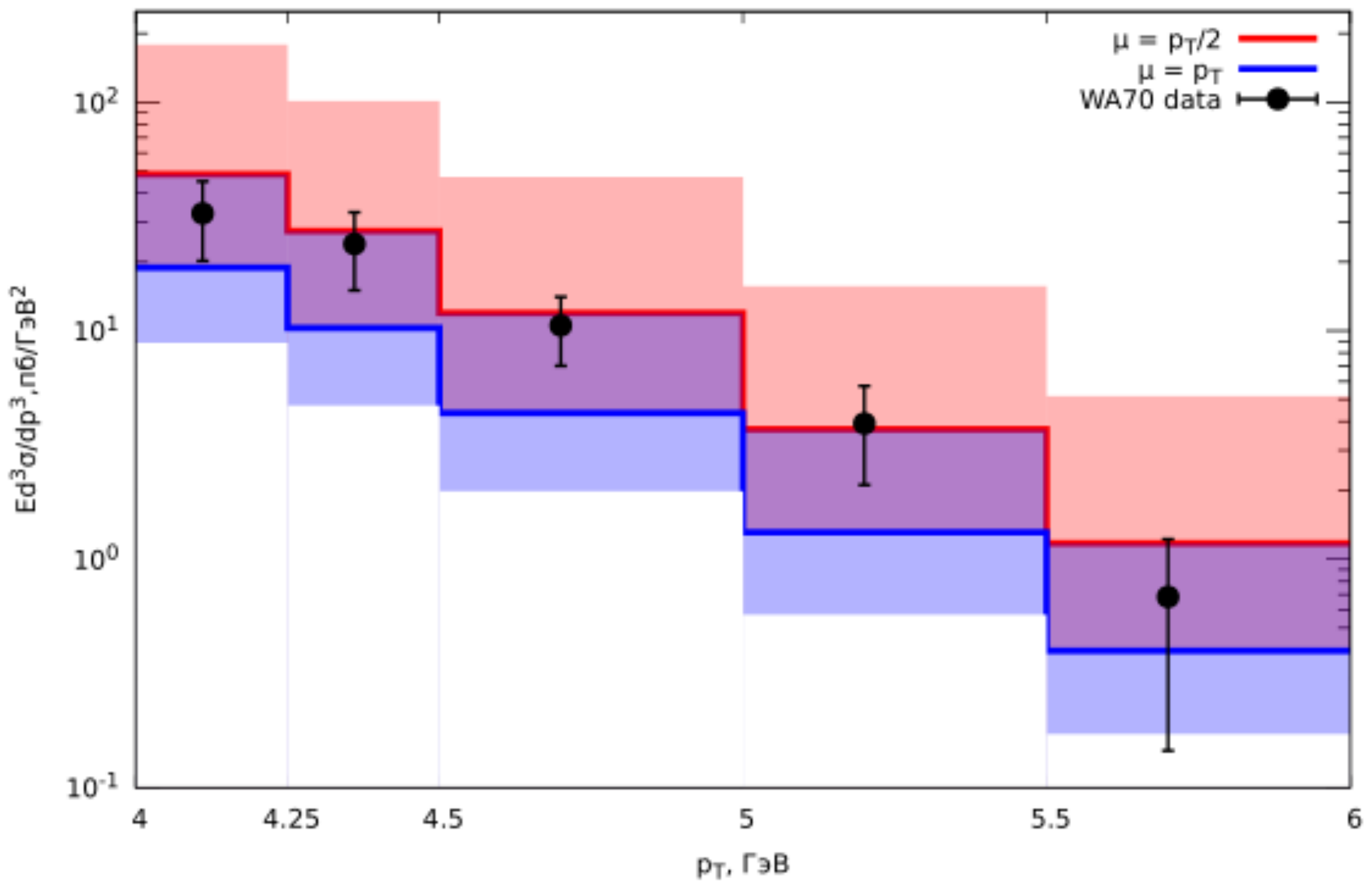


$\bar{q} + g \rightarrow \bar{q} + \gamma$

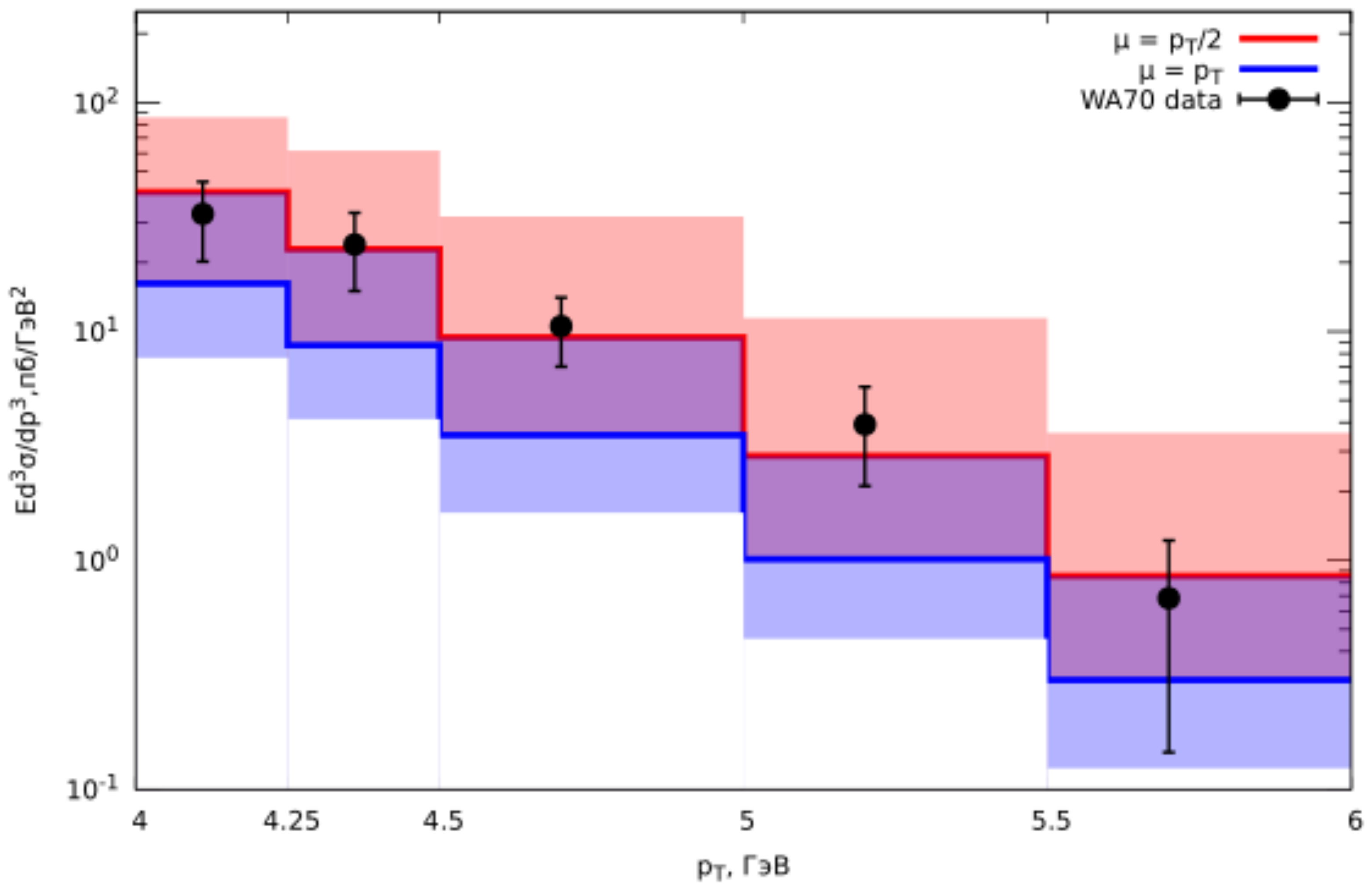


Results

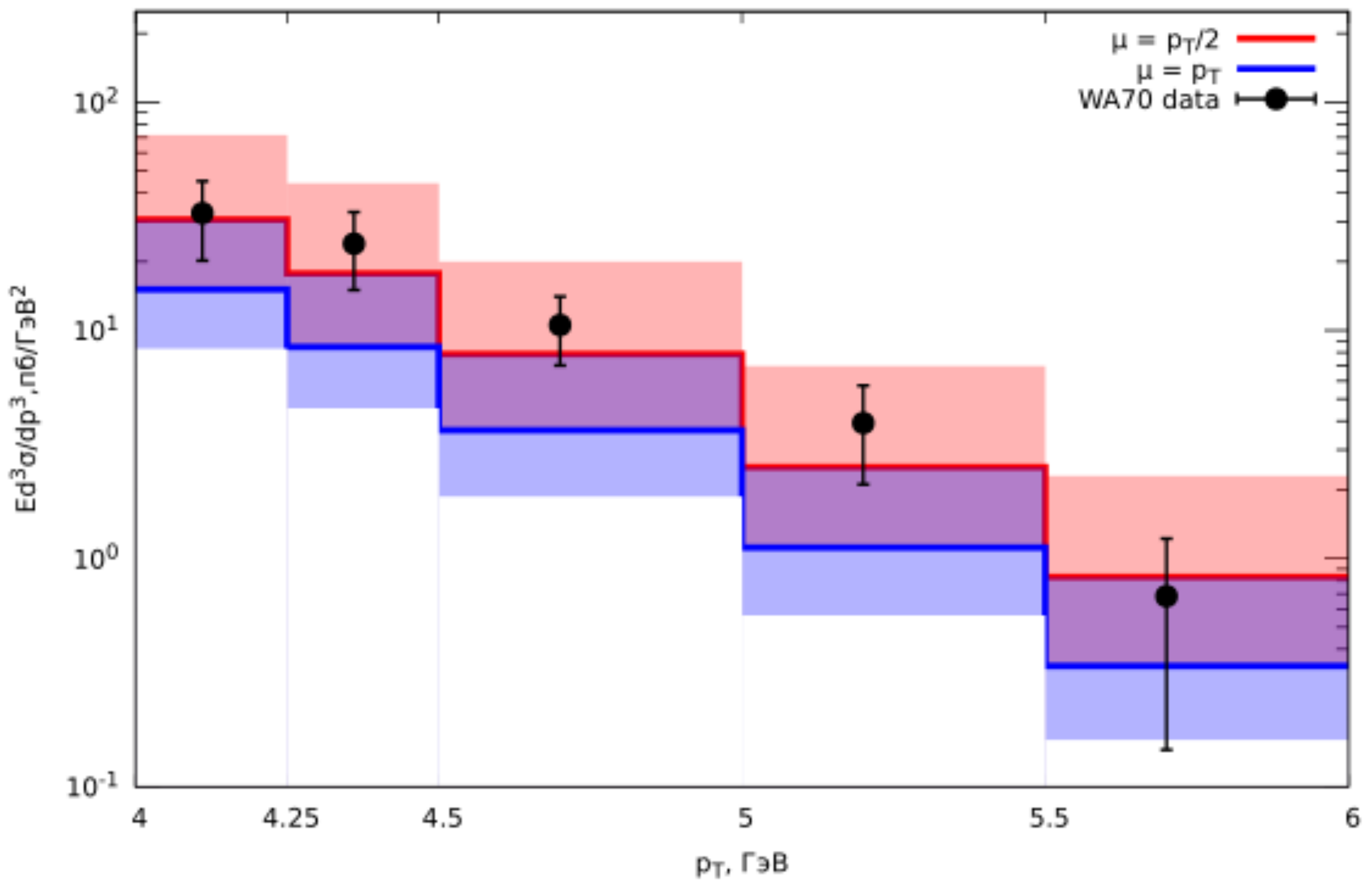
CERN WA70



a)



b)



c)

Comparison of predictions in CPM for direct photons differential cross section as function of photon transverse-momentum at $\sqrt{S} = 22.96$ GeV, $-0.05 < x_{F\gamma} < 0.05$.

PDFs sets: a) MSTW2008lo, b) CT18LO, c) NNPDF2_3.

Обсуждение результатов

CERN UA6

a) b) c)

Comparison of predictions in CPM for direct photons differential cross section as function of photon transverse-momentum at $\sqrt{S} = 24.3$ GeV, $-0.2 < y_\gamma < 1.0$.

PDFs sets: a) MSTW2008lo, b) CT18LO, c) NNPDF2_3.

Обсуждение результатов

CERN NA24

a) b) c)

Comparison of predictions in CPM for direct photons differential cross section as function of photon transverse-momentum at $\sqrt{S} = 23.75$ GeV, $-0.65 < y_\gamma < 0.52$.

PDFs sets: a) MSTW2008lo, b) CT18LO, c) NNPDF2_3.

Обсуждение результатов

CERN R110

a) b) c)

Comparison of predictions in CPM for direct photons differential cross section as function of photon transverse-momentum at $\sqrt{S} = 63.0$ GeV, $-0.8 < y_\gamma < 0.8$.

PDFs sets: a) MSTW2008lo, b) CT18LO, c) NNPDF2_3.

Results

$\mu = p_{T\gamma}$	$\bar{K} \pm \delta\bar{K}$		
	MSTW2008	CT18LO	NNPDF2_3
FNAL E704 ($\sqrt{S}$ = 19.4 ГэВ)	7.341± 1.054	8.513± 1.470	10.399± 1.195
CERN WA70 ($\sqrt{S}$ = 22.96 ГэВ)	2.438± 0.011	3.163± 0.070	3.109± 0.024
CERN NA24 ($\sqrt{S}$ = 23.75 ГэВ)	2.396± 0.623	3.031± 1.138	3.258± 0.959
CERN UA6 ($\sqrt{S}$ = 24.3 ГэВ)	3.069± 0.182	3.759± 0.194	3.812± 0.234
CERN R110 ($\sqrt{S}$ = 63 ГэВ)	2.057±0.215	2.198±0.271	2.657±0.395
Все данные	2.737±0.023	3.433±0.031	3.559±0.028

Results

$\mu = p_{T\gamma}/2$	$\bar{K} \pm \delta\bar{K}$		
	MSTW2008	CT18LO	NNPDF2_3
FNAL E704 ($\sqrt{S}$ = 19.4 ГэВ)	2.777± 0.297	3.361± 0.380	5.266± 0.394
CERN WA70 ($\sqrt{S}$ = 22.96 ГэВ)	0.834± 0.076	1.144± 0.006	1.419± 0.003
CERN NA24 ($\sqrt{S}$ = 23.75 ГэВ)	0.883± 0.097	1.210± 0.372	1.509± 0.218
CERN UA6 ($\sqrt{S}$ = 24.3 ГэВ)	1.162± 0.099	1.456± 0.086	1.821± 0.163
CERN R110 ($\sqrt{S}$ = 63 ГэВ)	1.184±0.159	1.321±0.184	1.787±0.313
Все данные	1.003±0.083	1.315±0.014	1.709±0.034

Summary

It follows that for better agree the experiment with the theoretical predictions it is necessary:

- take into account calculations in NLO;
- perform calculations on the factorization scale: $\mu = p_{T\gamma}$.

Thank you for your attention!