Modeling photon radiation in soft hadronic collisions

Boris Kopeliovich
UTFSM Valparaiso

As far as the bremsstrahlung model turns out to be incorrect,
an alternative description of soft photon radiation is required.

Within the parton model radiation of a heavy photon of mass M (Drell-Yan) in the target rest frame has the form

$$\frac{d^4\sigma_{DY}}{dM^2\,dx_F\,d^2k_T}=\frac{\alpha_{em}}{3\pi M^2}\frac{x_1}{x_1+x_2}\int_{x_1}^{1}\frac{d\alpha}{\alpha^2}\sum_f Z_f^2\left\{q_f\left(\frac{x_1}{\alpha}\right)+q_{\bar f}\left(\frac{x_1}{\alpha}\right)\right\}\frac{d\sigma(qN\to\gamma^*X)}{d\ln\alpha\,d^2k_T}$$

$$\mathbf{x_1x_2=M^2/s;\quad 2x_2=\sqrt{x_F^2+4M^2/s}-x_F}\qquad \alpha=\mathbf{p_+^\gamma/p_+^q}$$

The hard scale is imposed by the large photon mass and for the quark distribution functions $\mathbf{q_f(x)}$ and $\mathbf{q_{\bar f}(x)}$ one can rely on DGLAP evolution and on the well measured structure function $\mathbf{F_2(x,M^2)}$.

UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

One cannot apply the DGLAP evolution to the quark distribution down to the soft limit of M=0.

We rely on

Quark-Gluon String model (QGSM)

A. Kaidalov, Phys.Lett. B116(1982)459

A. Kaidalov and M. Poghosyan, *Eur.Phys.J.C* 67 (2010) 397

or Dual Parton Model

A. Capella, U. Sukhatme, C-I Tan, J. Tran Thanh Van, Phys.Rept. 236(1994)225

A.Capella, A.Kaidalov, C.Merino, J.Tran Thanh Van, Phys.Lett.B 337 (1994) 358

which are nearly the same

So we calculate the factor $\left\{q_f\left(\frac{x_1}{\alpha}\right)+q_{\bar{f}}\left(\frac{x_1}{\alpha}\right)\right\}$ within QGSM

UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Color-dipole description of bremsstrahlung

The next factor in the radiation cross section is calculated within the color dipole approach

$$\frac{\mathbf{d}\sigma(\mathbf{qp}\to\gamma\mathbf{p})}{\mathbf{d}\ln\alpha\,\mathbf{d^2k_T}}$$

B.Kopeliovich, Hirschegg 1995
hep-ph/9609385

B.Kopeliovich, A.Schäfer, A.Tarasov,
Phys.Rev.C 59(1999)1609;
Phys.Rev.D 62 (2000) 054022

B.Kopeliovich, J.Raufeisen and A.Tarasov, Phys.Lett. B503(2001)91

B.Kopeliovich, A.Rezaeian, H-J.Pirner, I.Schmidt, Phys.Lett. B653(2007)210

B.Kopeliovich, E.Levin, A.Rezaeian, I.Schmidt, Phys.Lett. B675(2009)190

$$\frac{d^3\sigma^N(q\to q\gamma)}{d(\ln\alpha)\,d^2k_T}=\frac{1}{(2\pi)^2}\int d^2r_1\,d^2r_2\exp[i\vec{k}_T(\vec{r}_1-\vec{r}_2)]\,\Psi^*_{\gamma q}(\alpha,\vec{r}_1)\,\Psi_{\gamma q}(\alpha,\vec{r}_2)\,\sigma_\gamma(\vec{r}_1,\vec{r}_2,\alpha)$$

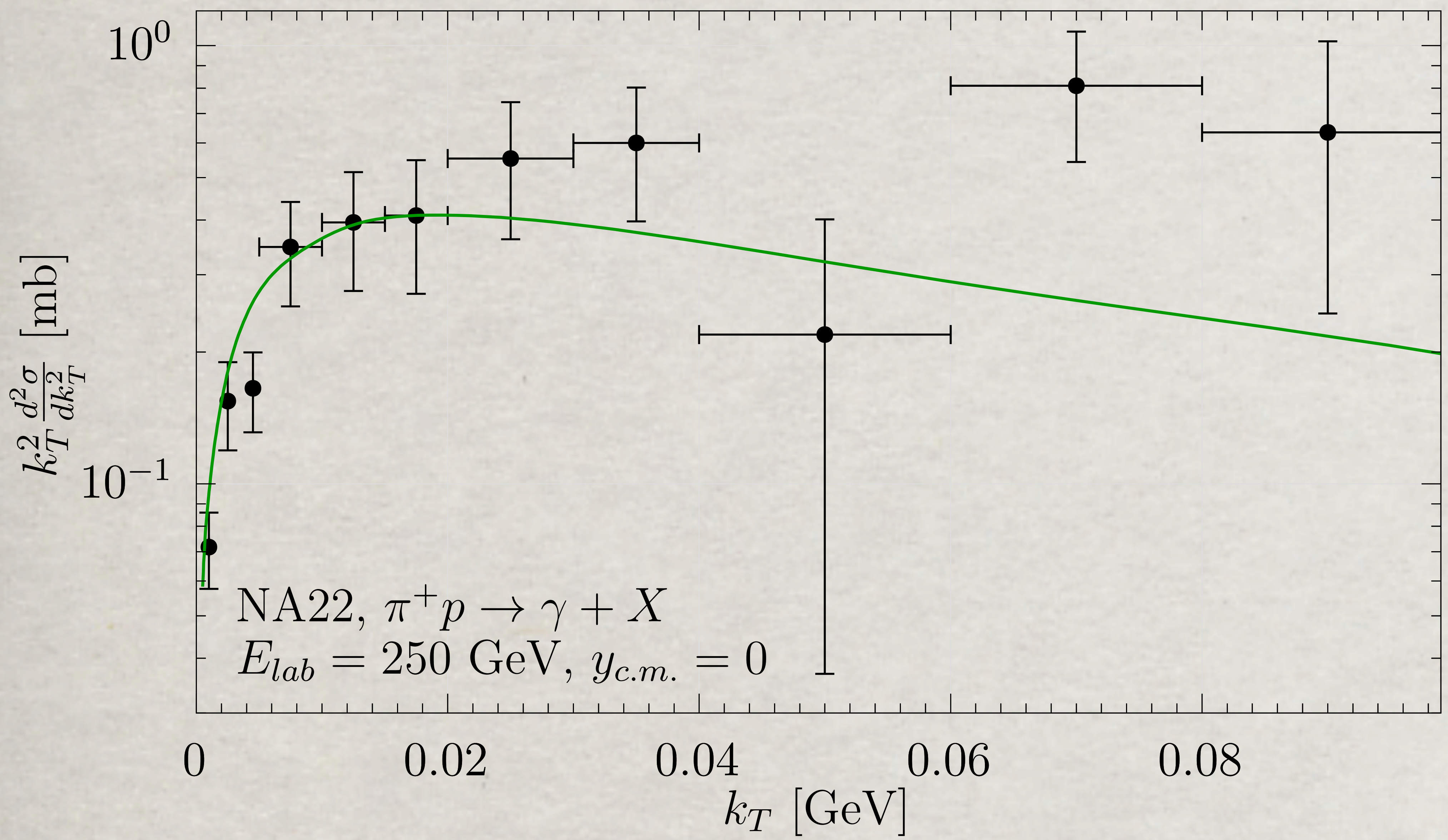
$$\sigma_\gamma(\vec{r}_1,\vec{r}_2,\alpha)=\frac{1}{2}\Big\{\sigma_{\bar{q}q}(\alpha r_1)+\sigma_{\bar{q}q}(\alpha r_2)-\sigma_{\bar{q}q}[\alpha(\vec{r}_1-\vec{r}_2)]\Big\}$$

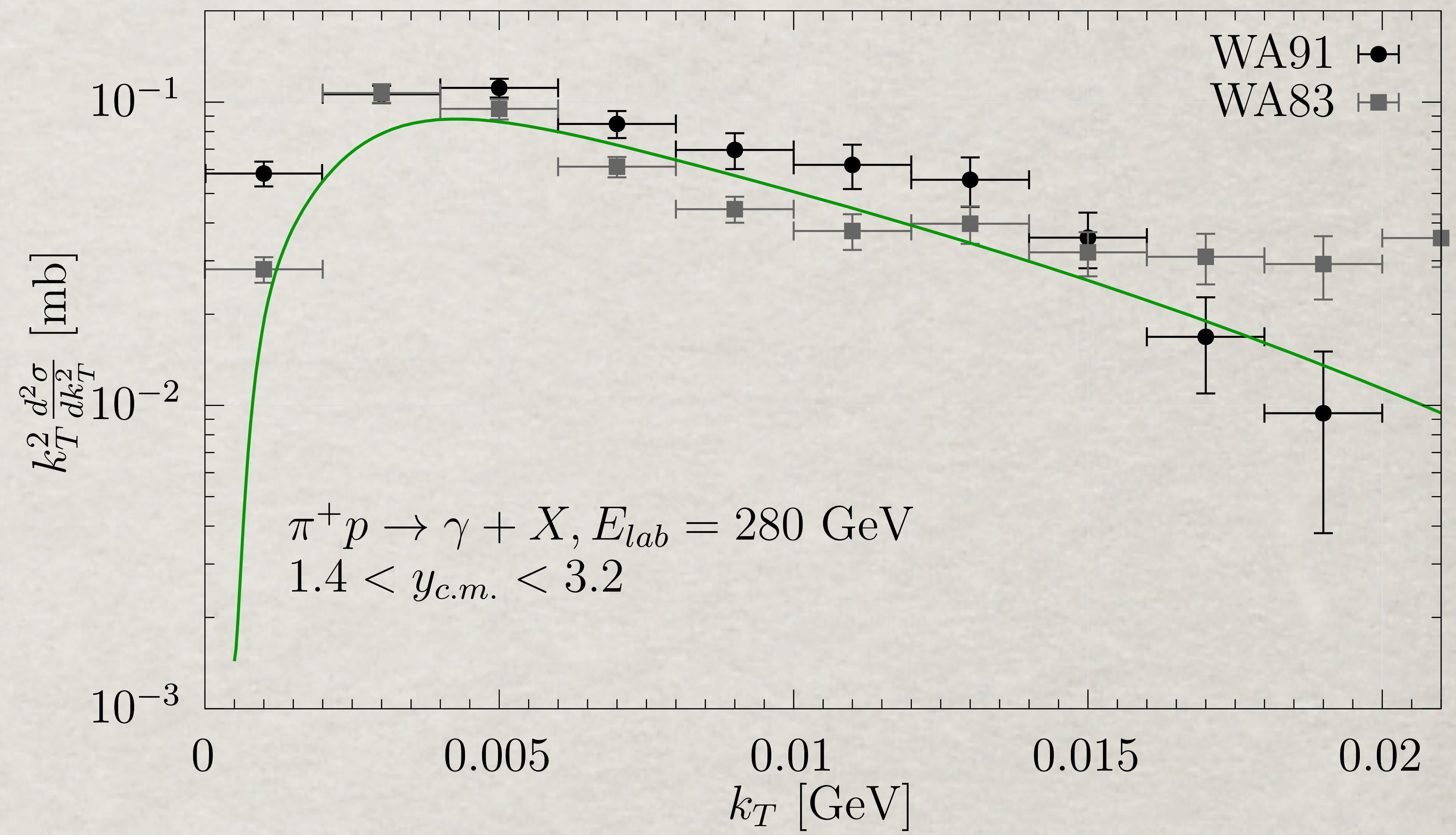
$$\mathbf{\Psi}_{\gamma\mathbf{q}}(\alpha,\mathbf{r})=\frac{\sqrt{\alpha_{\mathbf{em}}}}{\mathbf{2}\pi}\chi_{\mathbf{f}}\hat{\mathbf{O}}\chi_{\mathbf{i}}\mathbf{K_0}(\alpha\mathbf{m_q}\mathbf{r})$$

$$\hat{\mathbf{O}}=\tilde{\epsilon}^*[\mathbf{i}\mathbf{m_q}\alpha^{\mathbf{2}}(\tilde{\mathbf{n}}\times\tilde{\sigma})+\alpha(\tilde{\sigma}\times\tilde{\nabla})-\mathbf{i}(\mathbf{2}-\alpha)\tilde{\nabla}]$$

UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Data

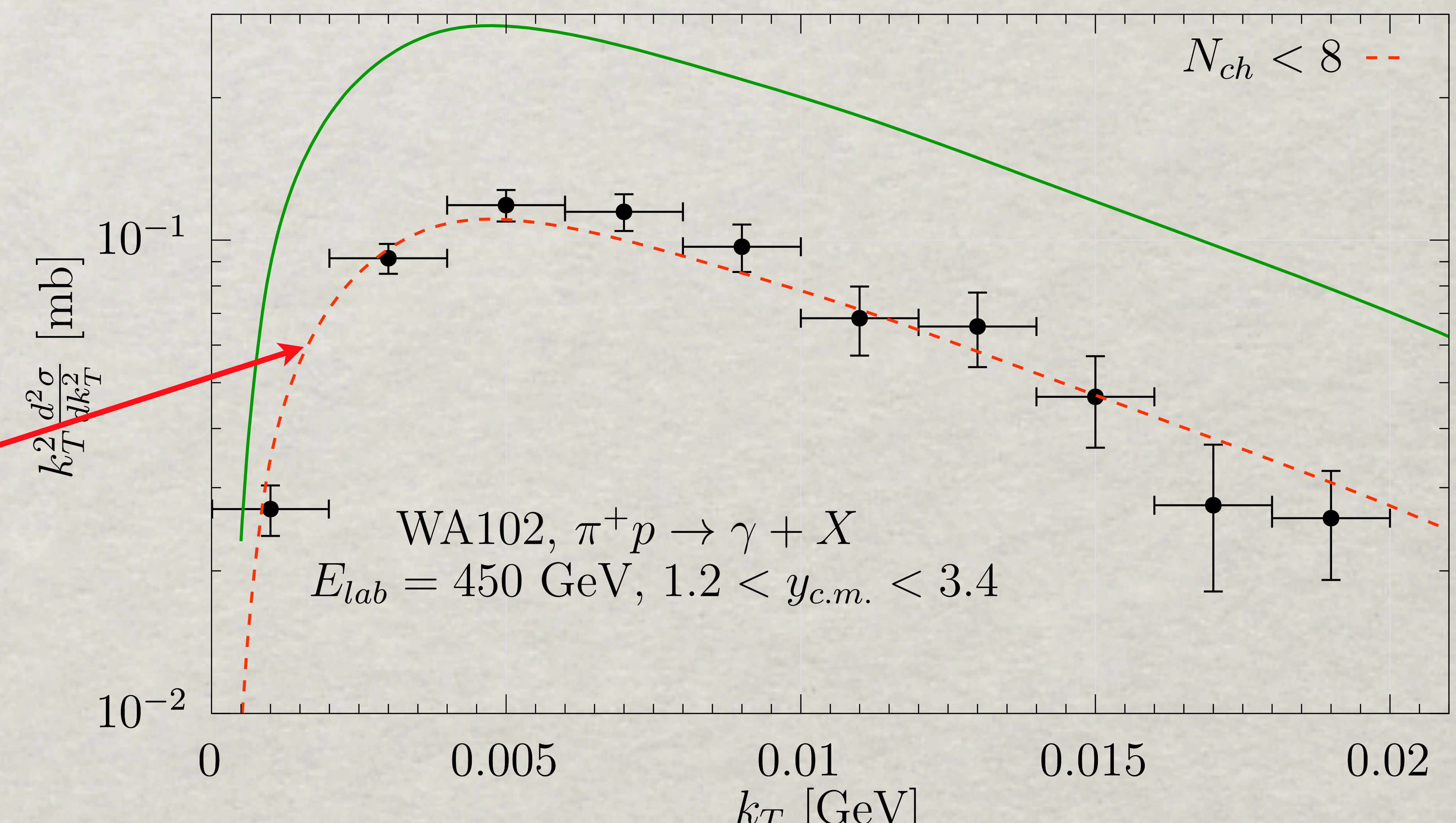




The primordial qT distribution of the quarks was taken into account: $\mathbf{\tilde{k}'_T = \tilde{k}_T - \alpha \tilde{q}_T}$

WA102 had a cut for number of charged tracks $\mathbf{N_{ch} < 8}$

That leads to the suppression factor 0.39 (QGSM)



UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Conclusions

The observed anomalous enhancement of low-kT photons is based on comparison with incorrect Bremsstrahlung Model, what led to so called soft photon puzzle.

Calculation based on the color dipole description of photon radiation well agree with data.