Prompt Photons at SPD

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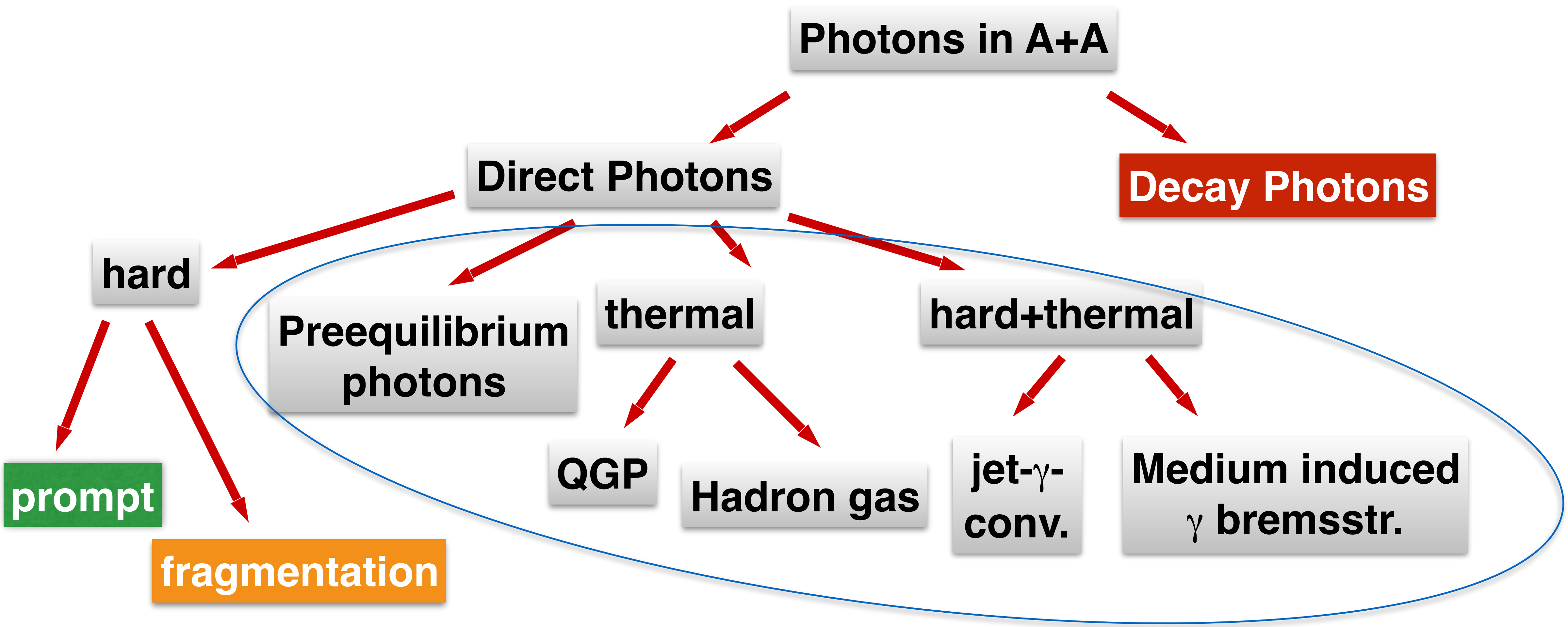
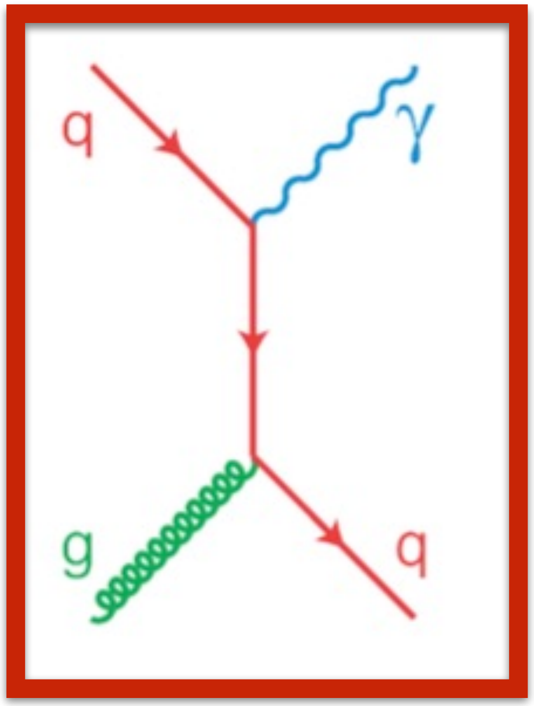
Production of photons in hadron collisions



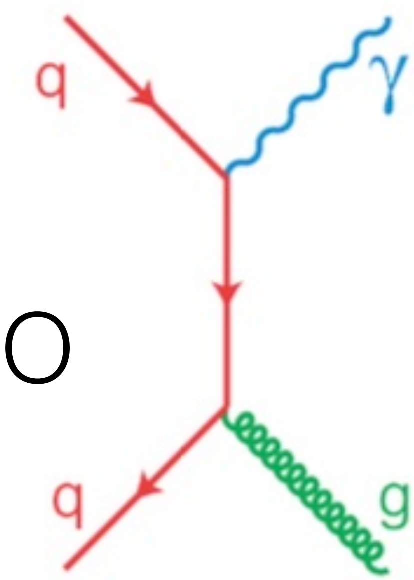
collective effects,
not important for pp or dd collisions

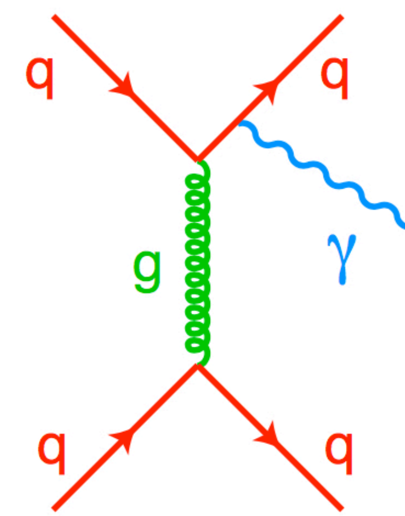
Please note, direct photons at MPD and SPD are different things!

Prompt photons



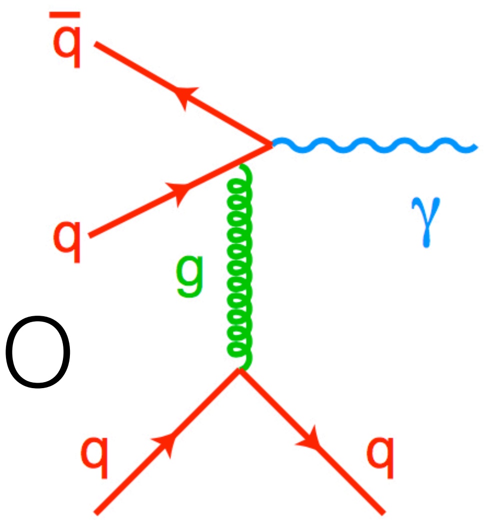
LO





Bremsstrahlung

NLO



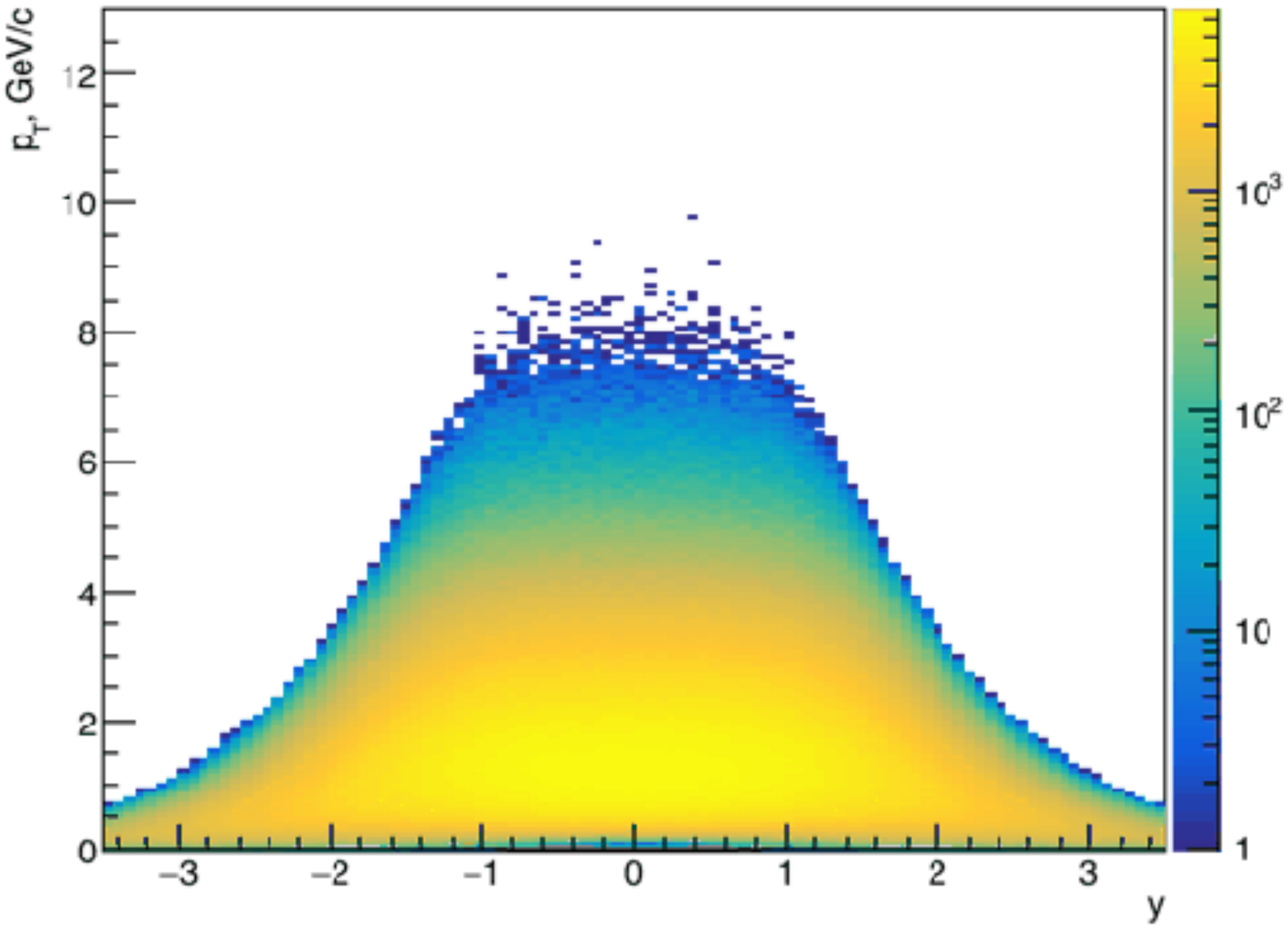
annihilation with scattering

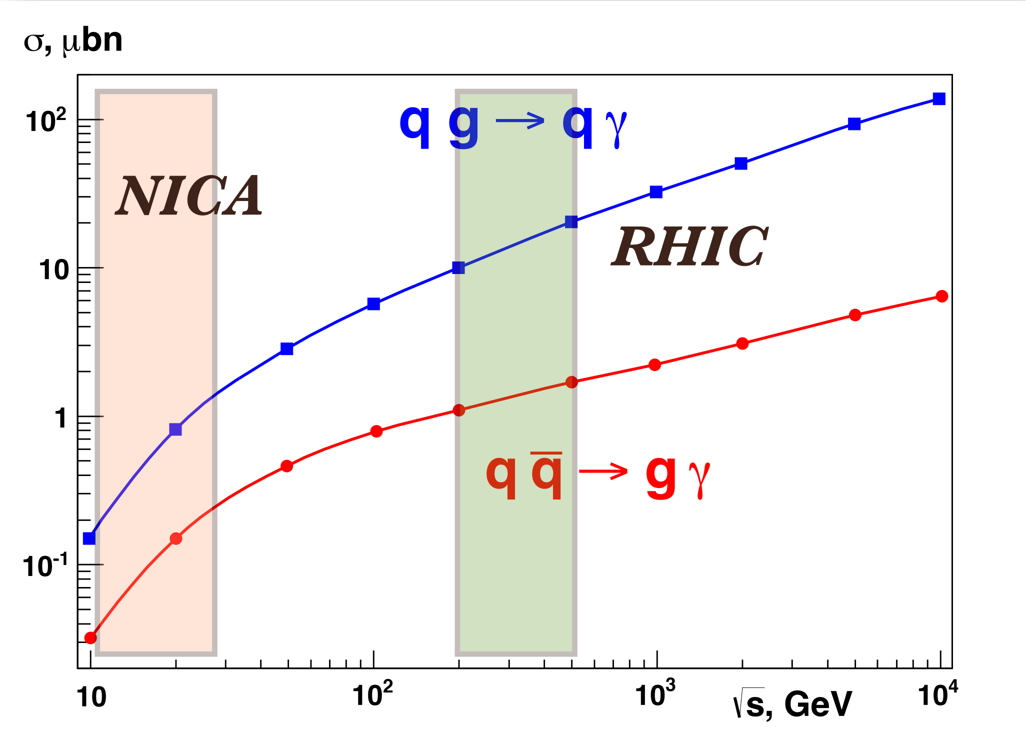
$$d\sigma_{AB} = \sum_{a,b=q,\bar{q},g} \int dx_a dx_b f_a^A(x_a,\mu^2) f_b^B(x_b,\mu^2) d\sigma_{ab\to\gamma X}(x_a,x_b,\mu^2).$$

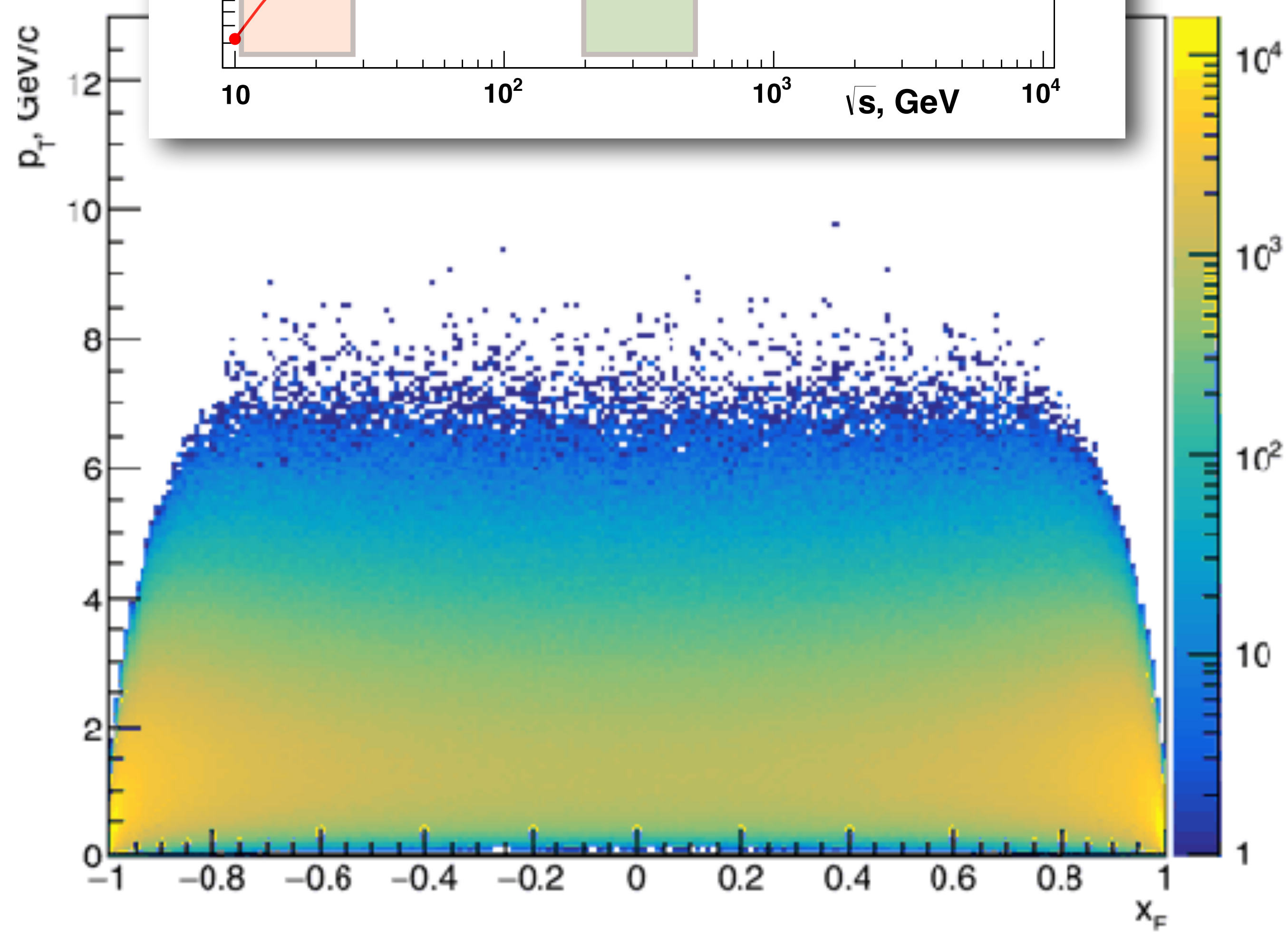
$\mu \sim p_T/2$

Measurement with prompt photons is direct access to gluon distributions in nucleons

Gluon Compton Scattering (GCS)

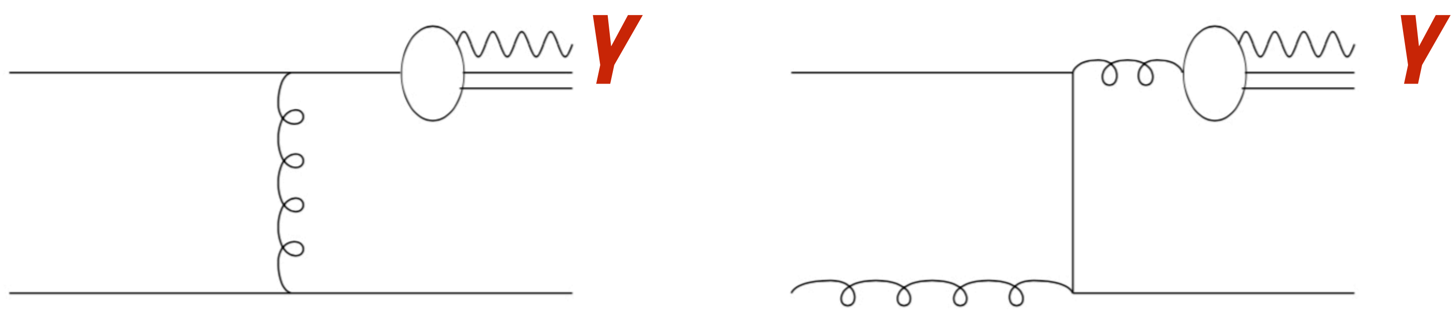


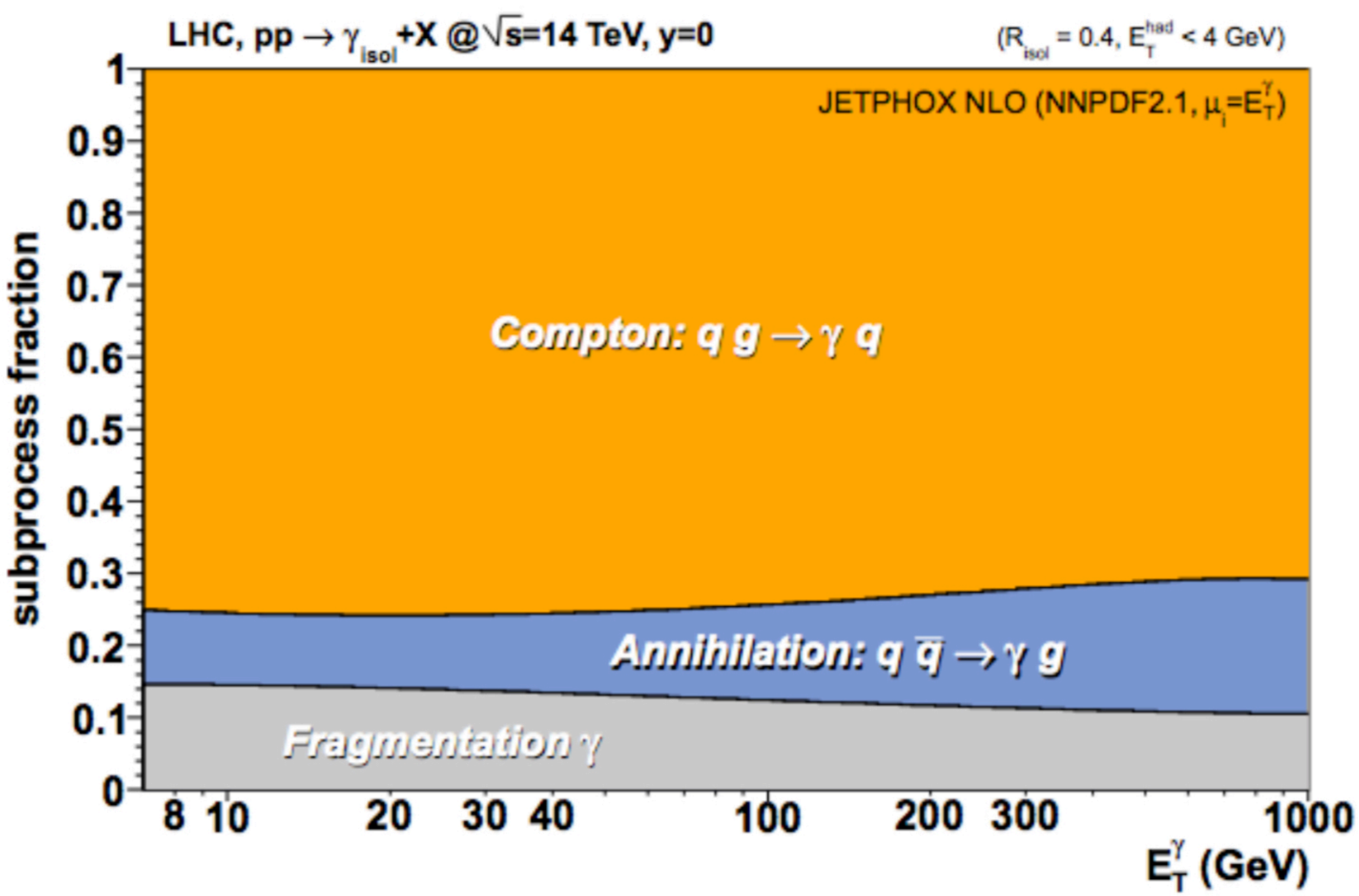




The region of **negative y** (or $\mathbf{x_F}$) is the most sensitive for gluon content of beam meson

Fragmentation photons

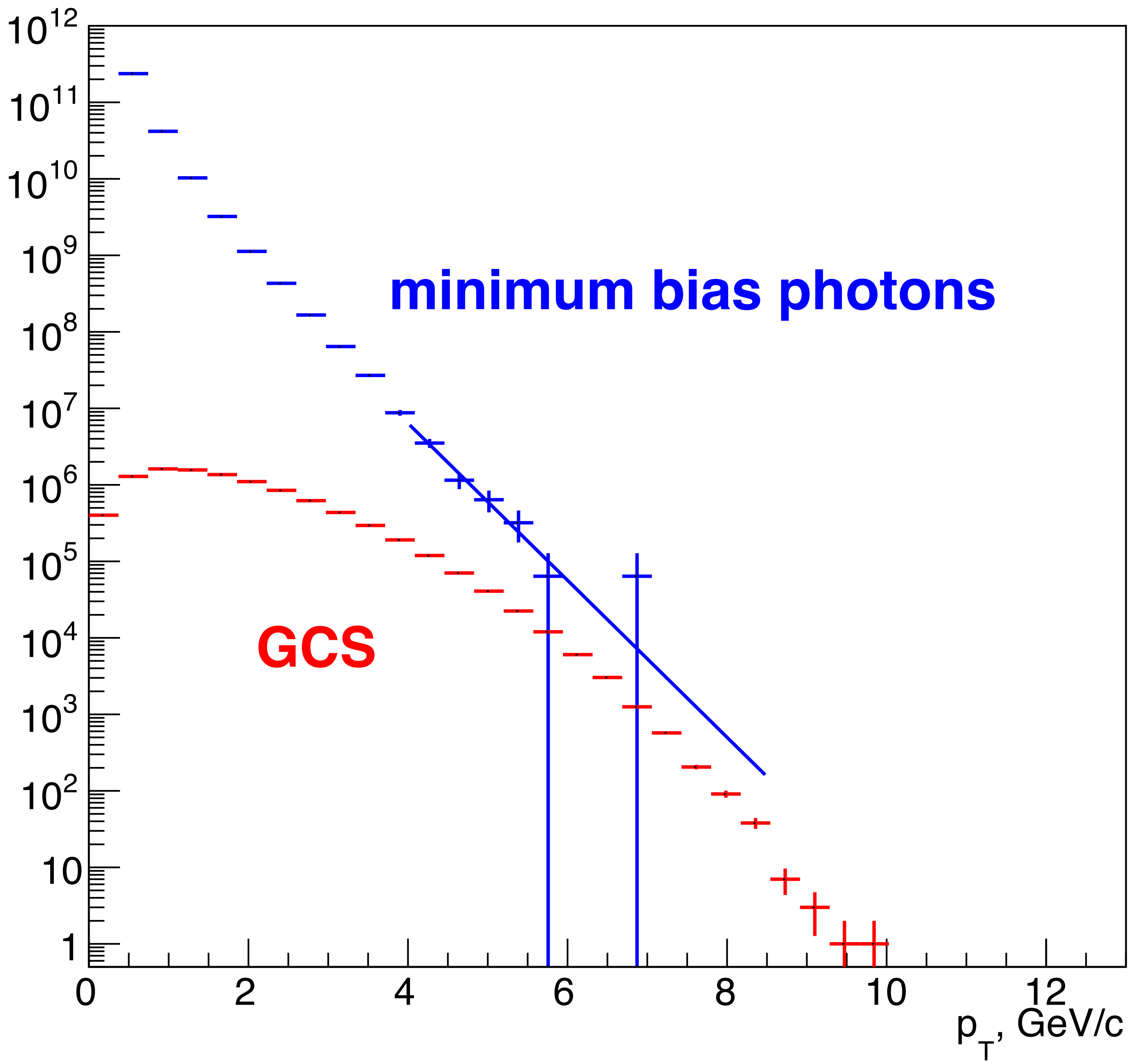


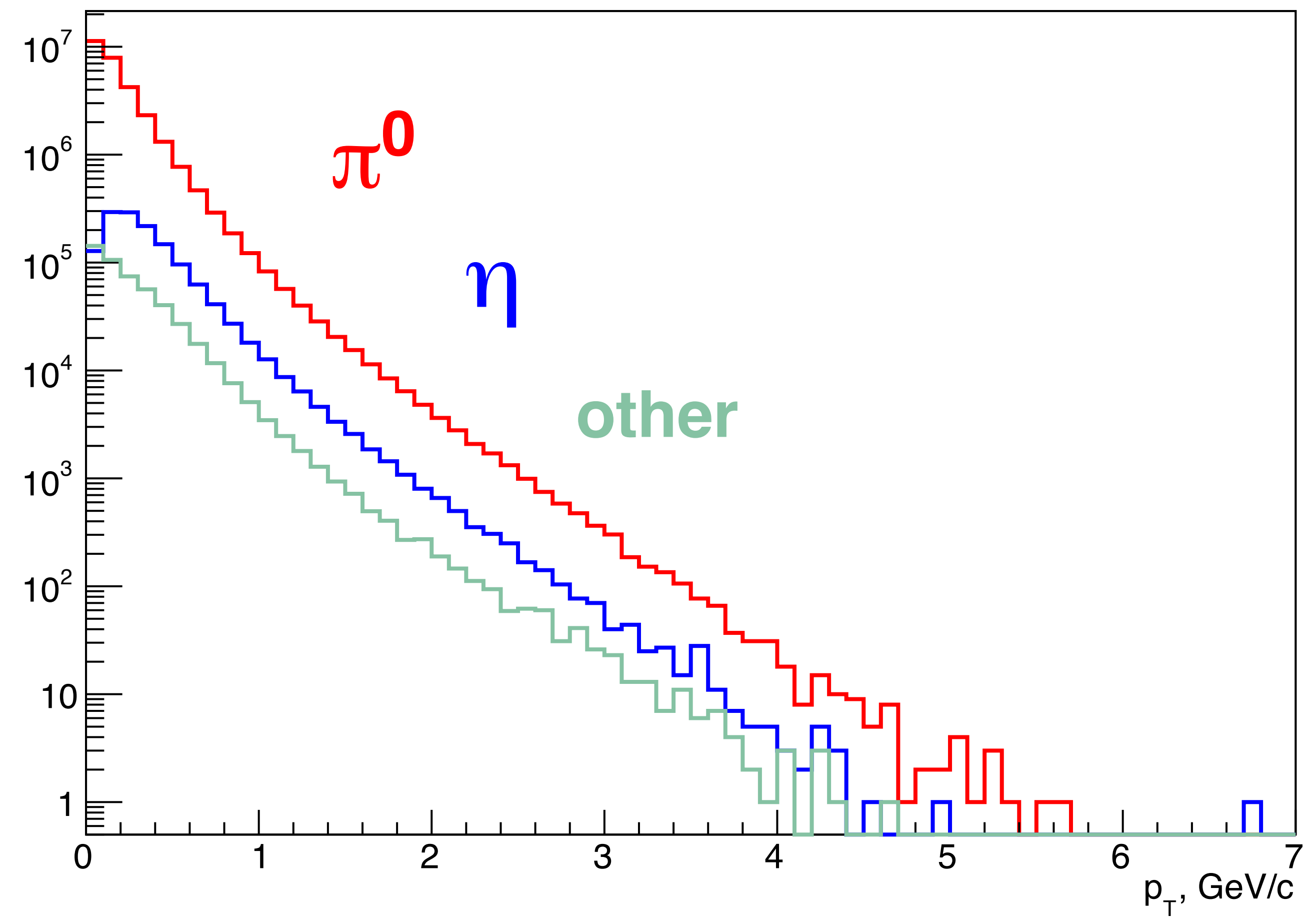


Relative contribution of fragmentation photons is below 15% even at much higher energies.

It can be calculated in LO and NLO

Decay photons





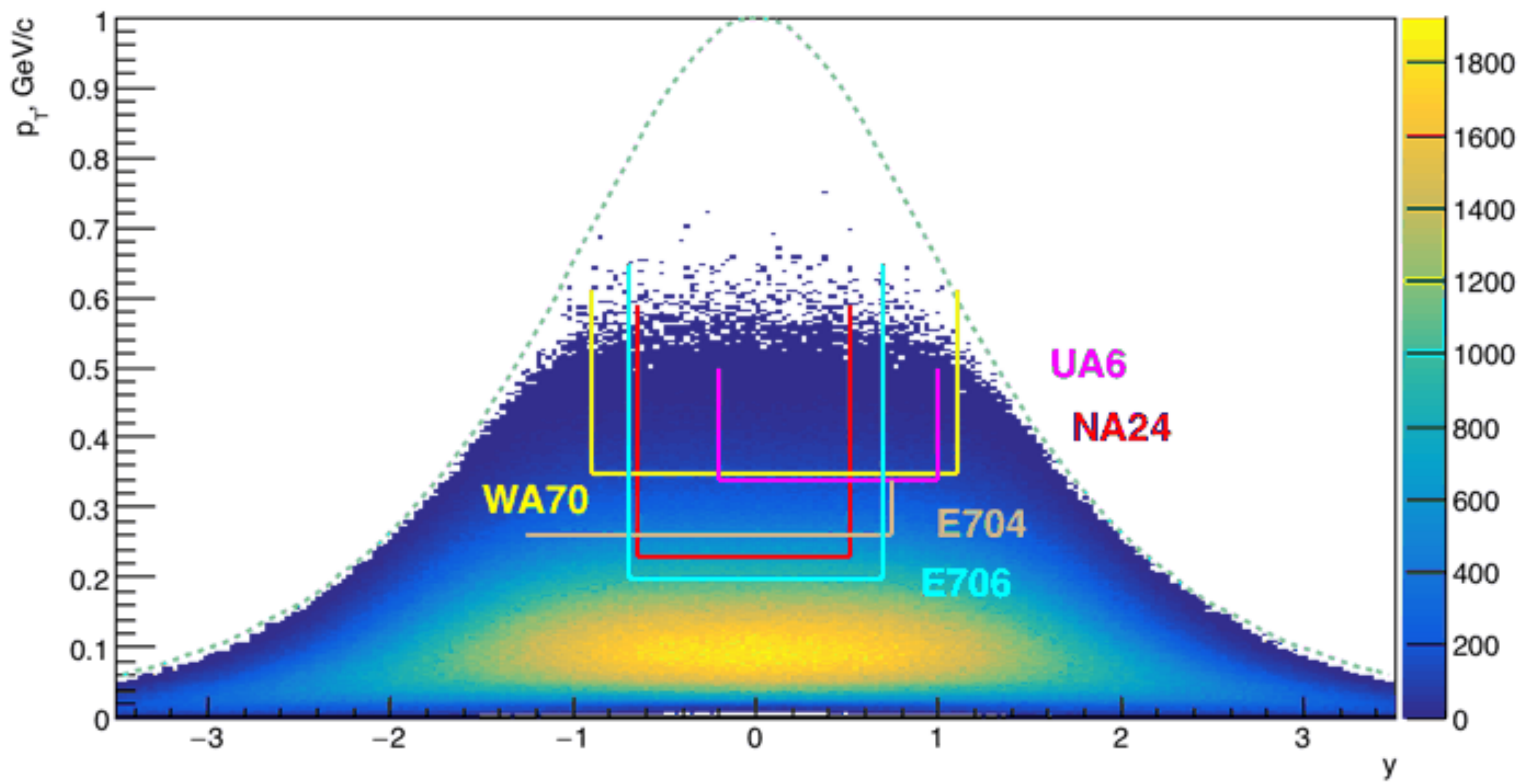
Even at very high p_T signal will dominate over background !

Previous studies at our energies

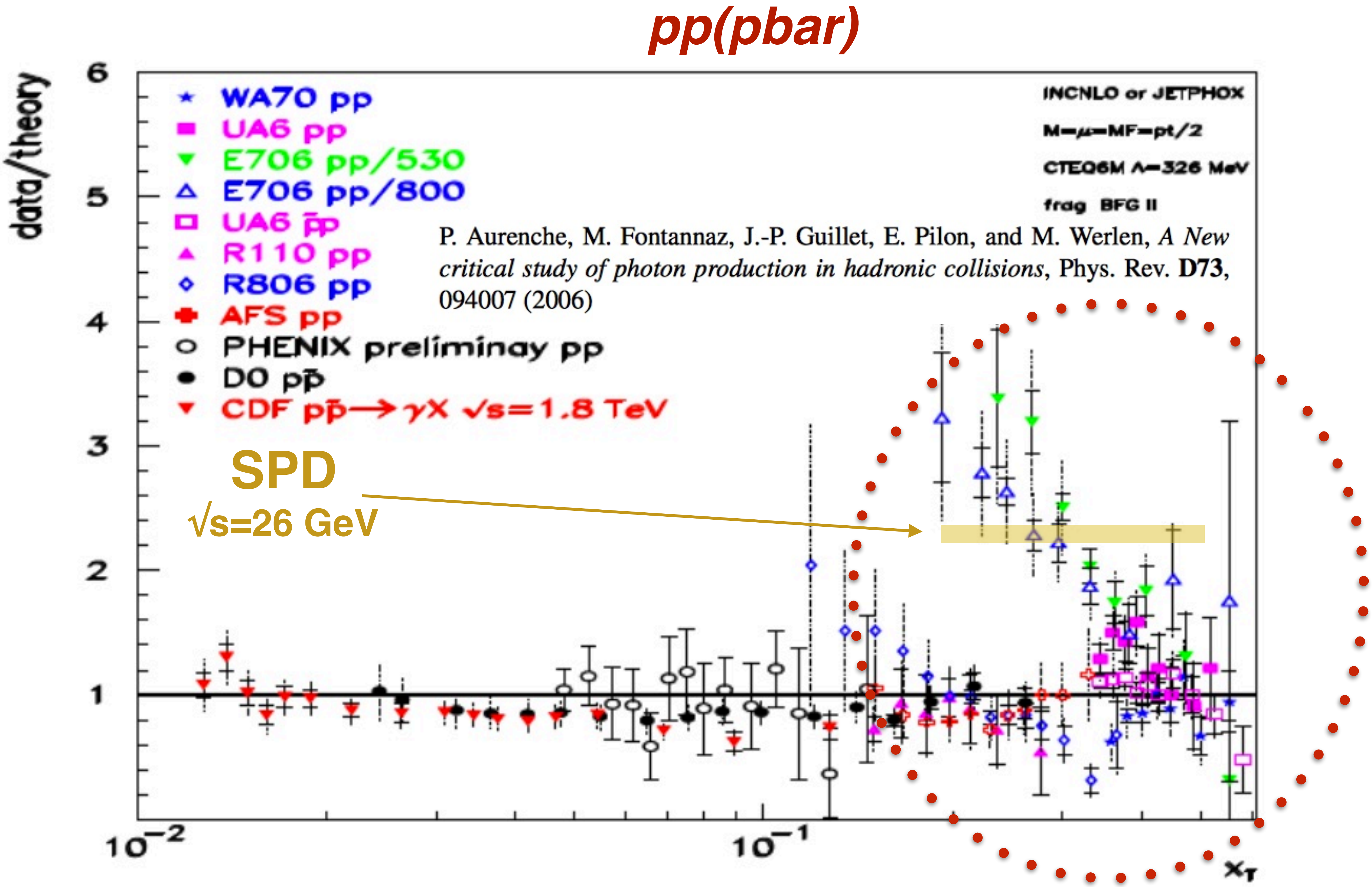
Experiment	Beam and target	$\sqrt{s}$, GeV	y range	x_T range
E95 (1979)	p; Be	19.4, 23.75	-0.7 – 0.7	0.15 – 0.45
E629 (1983)	p, π^+; C	19.4	-0.75 – 0.2	0.22 – 0.52
NA3 (1986)	p, π^+, π^-; C	19.4	-0.4 – 1.2	0.26 – 0.62
NA24 (1987)	p, π^+, π^-; p	23.75	-0.65 – 0.52	0.23 – 0.59
WA70 (1988)	p, π^+, π^-; p	22.96	-0.9 – 1.1	0.35 – 0.61
E706 (1993)	p, π^-; Be	30.63	-0.7 – 0.7	0.20 – 0.65
E704 (1995)	p; p	19.4	<0.74	0.26 – 0.39
UA6 (1993,1998)	$\bar{p}$; p	24.3	-0.2 – 1.0	0.34 – 0.50

$x_T=2p_T/\sqrt{s}$

Low-energy measurements



Previous results: pp(pbar)



Spin asymmetries with prompt photons

Single transverse spin asymmetry

$$A_N = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

I. Shmidt, J. Soffer, J.J. Yang, Phys. Lett. B 612 (2005)

gluon Sivers function

$$\sigma^{\uparrow} - \sigma^{\downarrow} = \sum_i \int_{x_{min}}^{1} dx_a \int d^2\mathbf{k}_{Ta} d^2\mathbf{k}_{Tb} \frac{x_a x_b}{x_a - (p_T/\sqrt{s})\, e^y} \Big[q_i(x_a, \mathbf{k}_{Ta}) \boxed{\Delta_N G(x_b, \mathbf{k}_{Tb})} \times \frac{d\hat{\sigma}}{d\hat{t}}(q_i G \to q_i \gamma) + G(x_a, \mathbf{k}_{Ta}) \Delta_N q_i(x_b, \mathbf{k}_{Tb}) \frac{d\hat{\sigma}}{d\hat{t}}(G q_i \to q_i \gamma) \Big]$$

where $q(x_{a,b}, k_{Ta,b})$ and $G(x_{a,b}, k_{Ta,b})$ are quark and gluon distribution functions and $\Delta_N q(x_{a,b}, k_{Ta,b})$

Double longitudinal spin asymmetry

$$A_{LL} = \frac{(\sigma_{++} + \sigma_{--}) - (\sigma_{+-} + \sigma_{-+})}{(\sigma_{++} + \sigma_{--}) + (\sigma_{+-} + \sigma_{-+})}$$

G. Bunce et. al. Ann.Rev.Nucl.Part.Sci. 50:525-575,2000

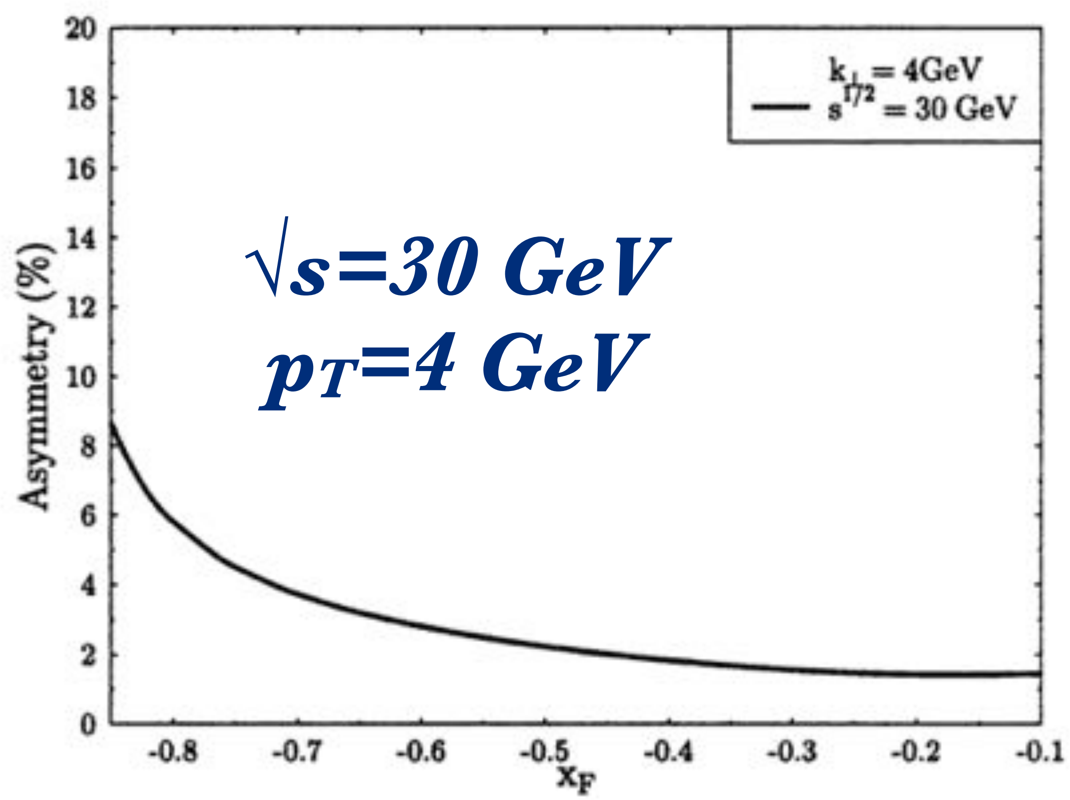
gluon polarization

$$A_{LL} \approx \frac{\boxed{\Delta g(x_1)}}{g(x_1)} \cdot \boxed{\left[\frac{\sum_q e_q^2 [\Delta q(x_2) + \Delta \bar{q}(x_2)]}{\sum_q e_q^2 [q(x_2) + \bar{q}(x_2)]} \right]} + (1 \leftrightarrow 2)$$

A_1^P - known from DIS

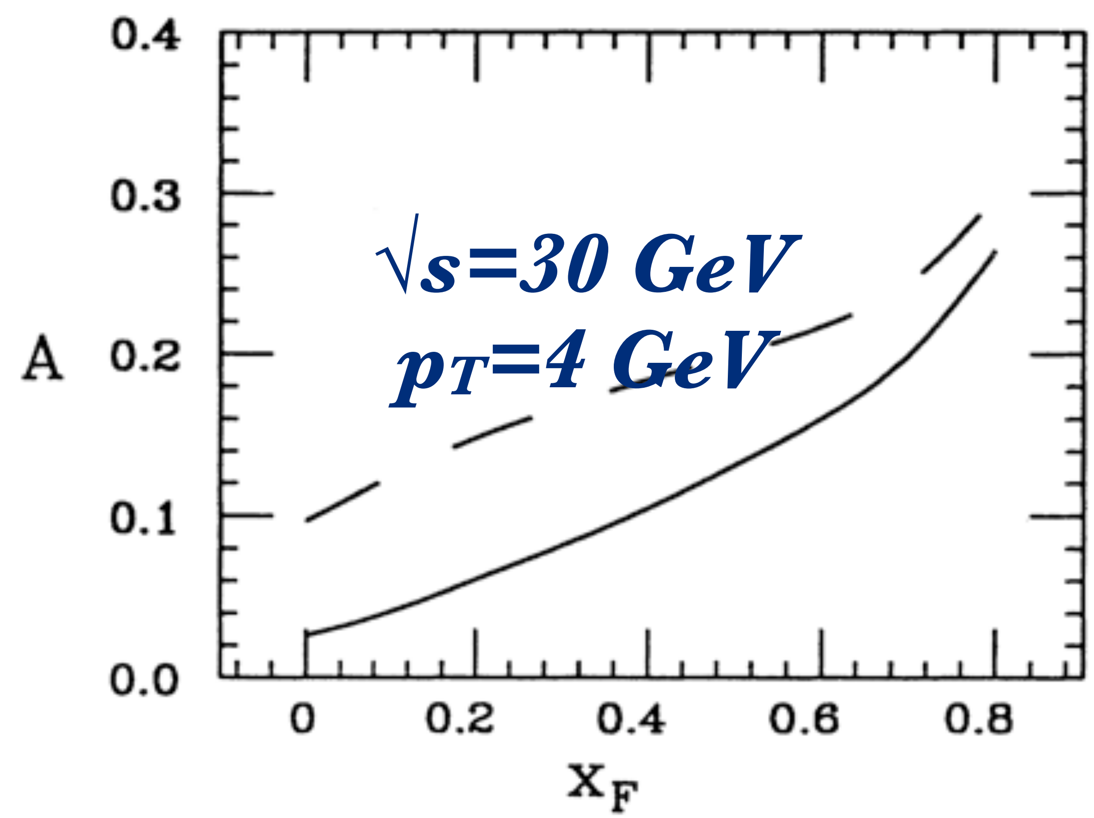
Prediction for A_N

For negative x_F:



N. Hammon et al.
J. Phys. G: Nucl. Part. Phys. 24 991(1998)

For positive x_F:

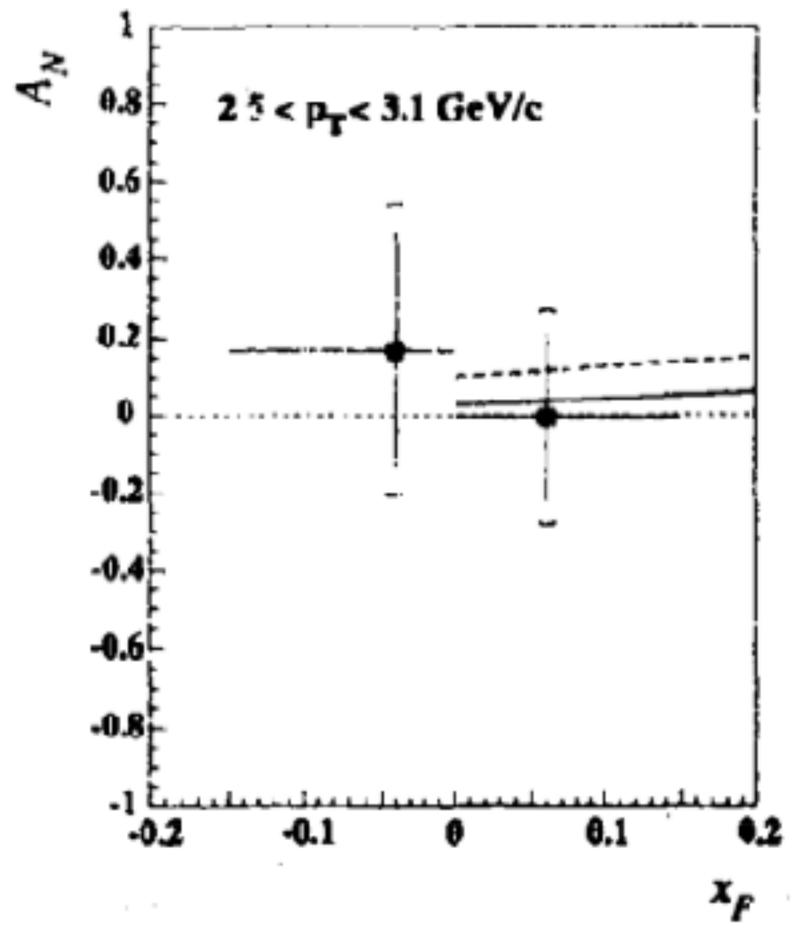


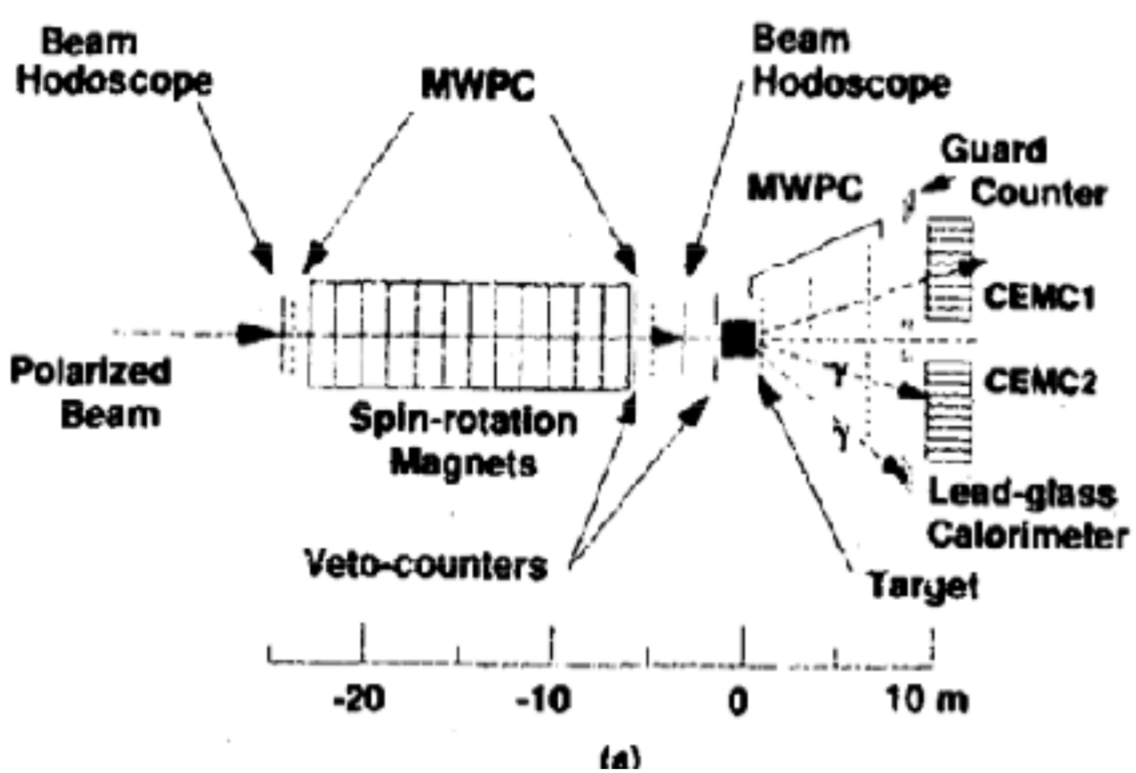
J. Qui and G. Sterman, Phys. Rev. Lett. 67 (1991) 2264

Single spin asymmetries at √s=19.4 GeV

Polarized measurement at FNAL E704 *Phys. Lett. B 345 (1995)*

- *Fixed target.*
- *Polarized proton beam from Λ decay*
- *2.5 GeV/c <p_T< 3.1 GeV/c*
- *π^0 mass resolution - 10.5 MeV*
- *473 prompt photon candidates (including 220+-22 background events)*





Signal-to-background ratio

The main background is coming from 2γ decays of π^0 and η. Effective reconstruction of such decays is the main way to suppress the background.

$$S/B = N_{\gamma\ prompt\ rec} / N_{bkg} = a\, N_{\gamma\ prompt} / a(1-a)\, N_{\pi 0} \sim 1/(1-a)$$

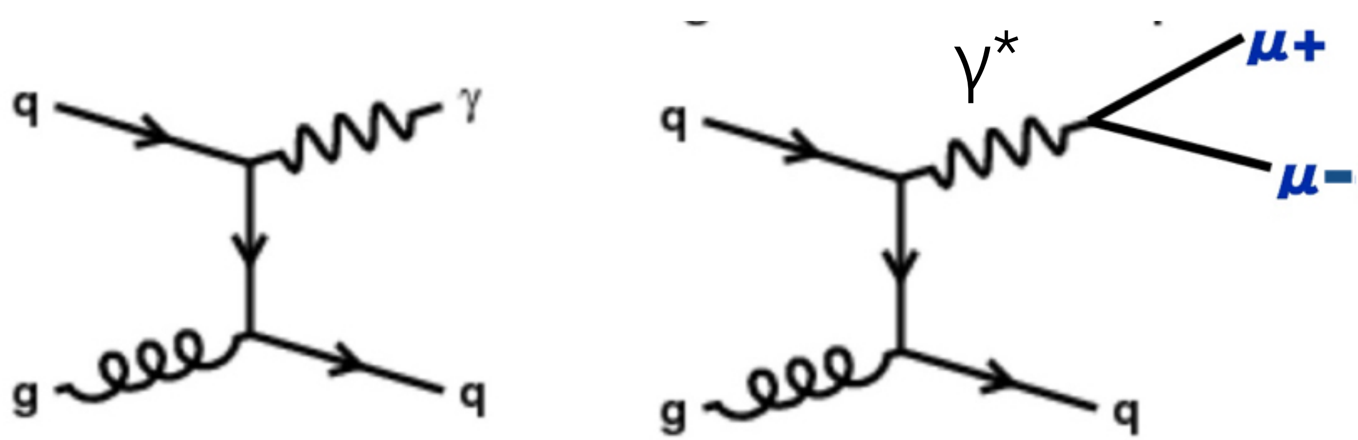
a - efficiency of photon reconstruction

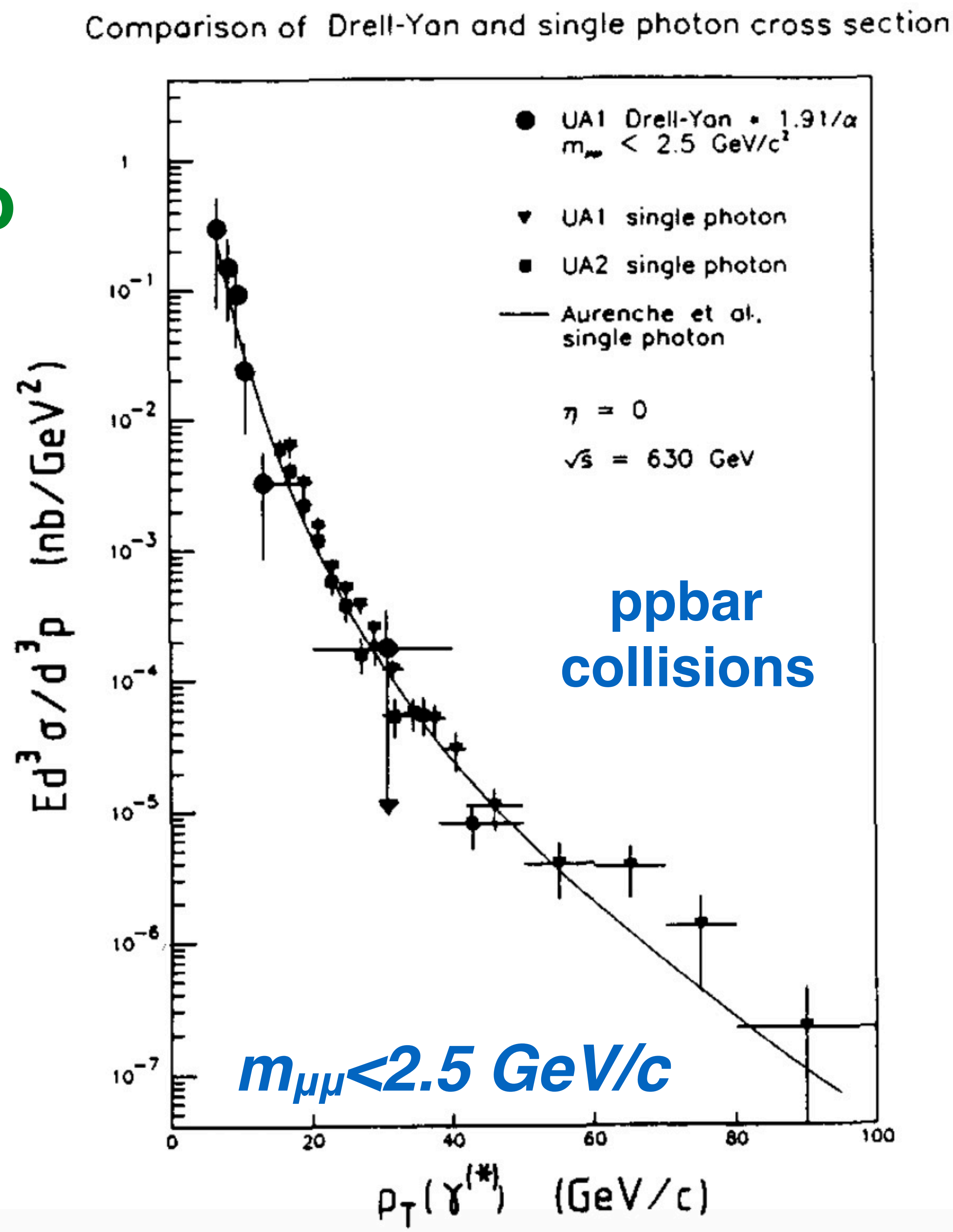
So, change of **a** form 0.9 to 0.6, for instance, reduces S/B ratio by the factor of 4, not 1.5 !

Prompt photons and DY

Phys.Lett. B209 (1988) 397-406 (1988)

Production of low-mass dimuon pairs is a process very similar to prompt photon production





— two orders of magnitude smaller cross section

— possibility to achieve low-p_T region

Summary

- Unpolarized and polarized physics with prompt photons looks very attractive
- All the measurements at energy scale ~20 GeV were performed with pion and proton beams only 20-30 years ago It is a good time to come back with new level of experimental techniques and theoretical understanding
- We have good chance to perform such kind of measurements at SPD detector
- Background conditions for studies with prompt photons are quite hard. So the SPD detector should be really optimized.