The study of backgrounds in direct photon production at SPD NICA energies.

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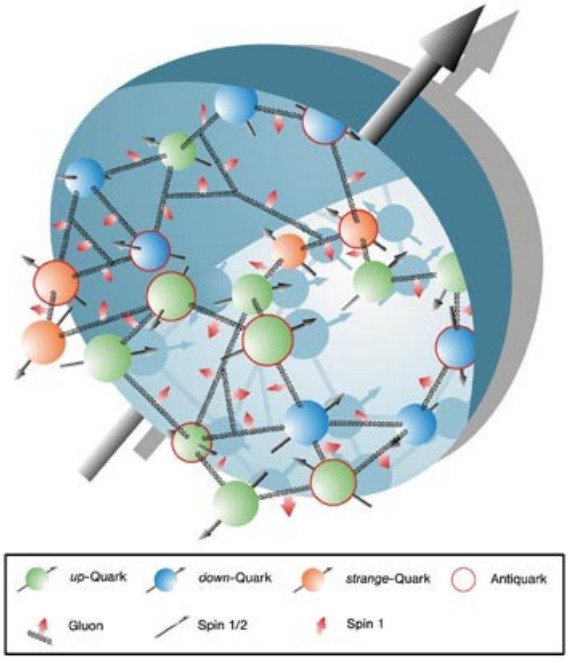
Motivation

- The direct photon production in proton-proton collisions, both inclusive and heavy-meson-associated, is an important source of information on gluon distribution function inside the proton.
- The studies of transverse single-spin and double longitudinal asymmetries in polarized-beam collisions → the information of the spin gluon content.
- The study of direct photon production is one of the important tasks of the physical program at Spin Physics Detector (SPD) at NICA Collider.



Recognize the direct photons from the background

Motivation


SPD
(Detector)
BM@N (Detector)
Extracted beam
Heavy Ion
Linac
Collider
MPD
(Detector)
E-cooling
LU-20
Nuclotron
Booster
NICA

Photon associated J/Psi production

Investigated process ? The overall scheme of Spin Physics Detector

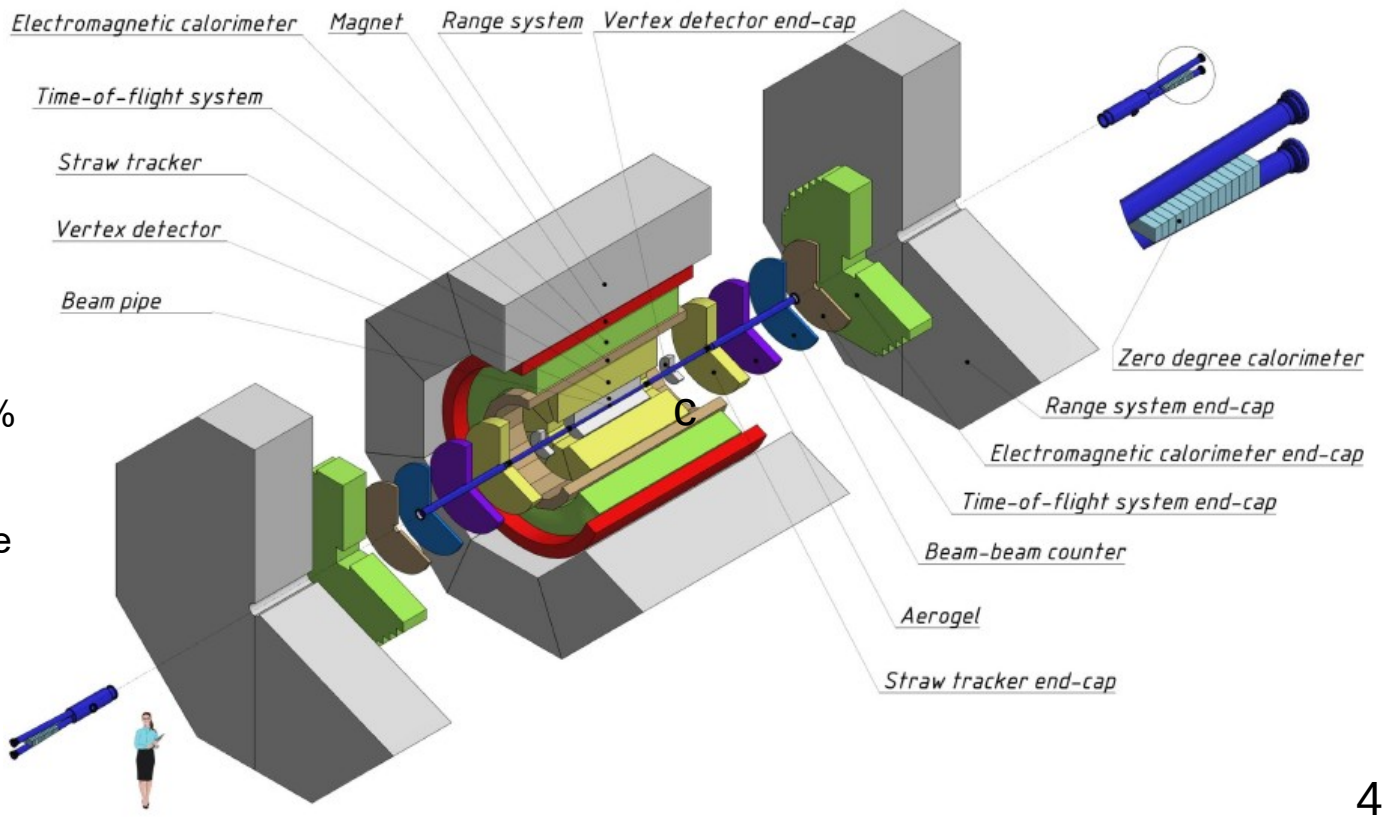
$$g+g \rightarrow J/\psi\left(3S_1^{(1)}\right)+\gamma$$

$$J/\psi\left(3S_1^{(1)}\right) \rightarrow \mu^- + \mu^+$$

J/ψ candidate

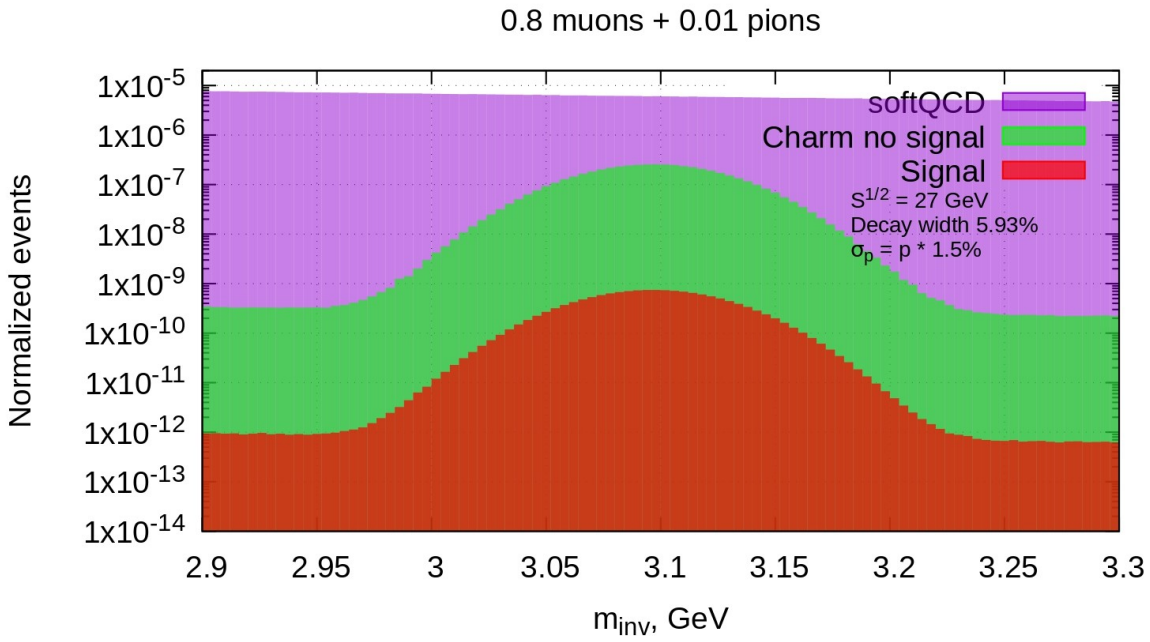
Experimental probabilities:
– register muon: 80%
– misidentify a pion as a muon: 1%
– density $W(p, p_{true})$ to obtain the experimental value of the muon momentum *p* while the exact value of the muon momentum is p_{true}

$$W(p, p_{true}) = \frac{e^{-\left(\frac{p-p_{true}}{\sqrt{2}\cdot 0.015\, p_{true}}\right)^2}}{\sqrt{2\pi}\cdot 0.015\, p_{true}}$$



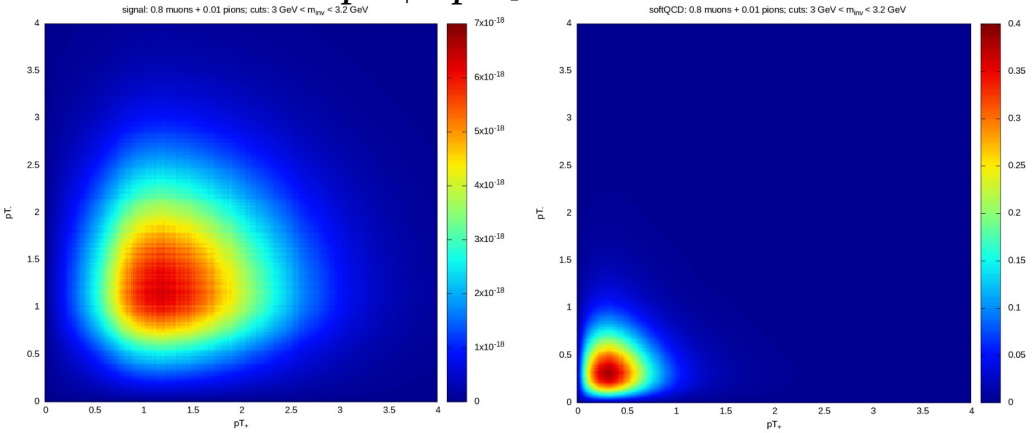
Pythia8: signals and backgrounds

- The signal process: $g+g \rightarrow J/\psi\left(3S_1^{(1)}\right)+\gamma$ (μ^-, μ^+) invariant mass distribution
- Backgrounds:
  - Hard QCD: $g+g \rightarrow c\bar{c}\left(3S_1^{(1)}\right)+g,$
    $q+g \rightarrow c\bar{c}\left(3S_1^{(8)}\right)+q,$
    $q+\bar{q} \rightarrow c\bar{c}\left(3S_1^{(8)}\right)+g,$
    $q+g \rightarrow c\bar{c}\left(3P_J^{(8)}\right)+q,$
    $\ldots$
  - Soft QCD: minimum bias events

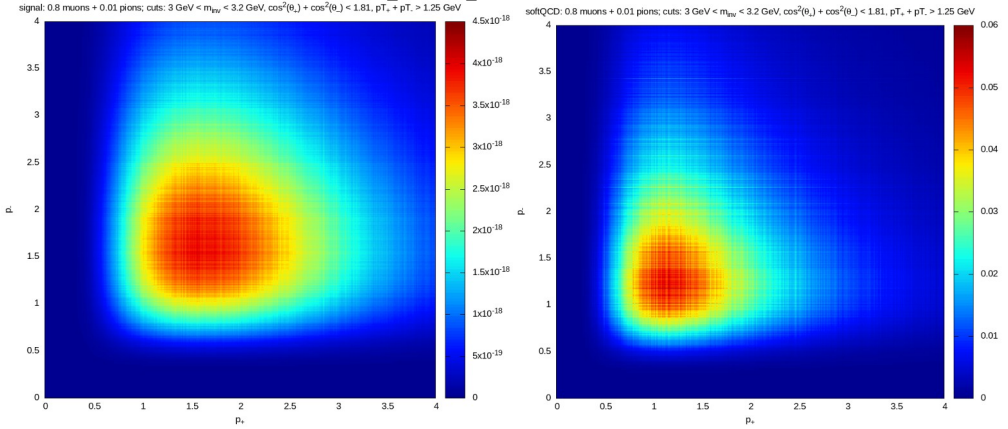


Generator-level kinematic cuts

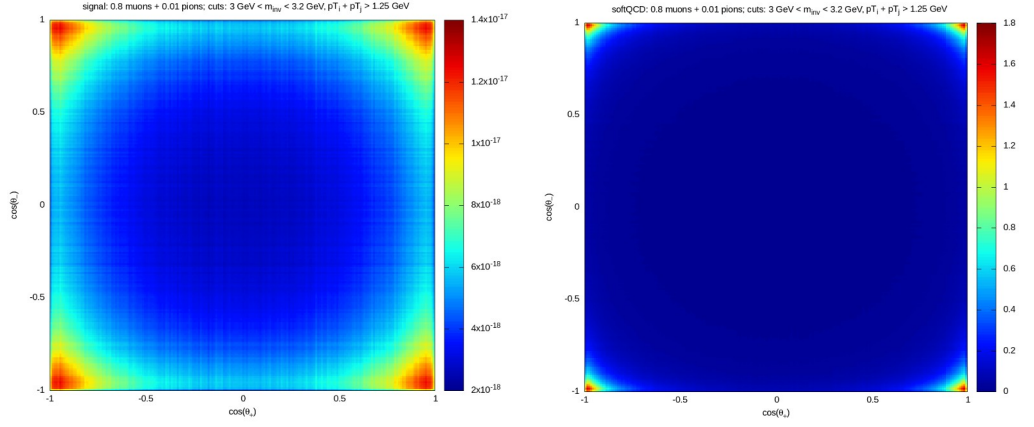
$pT_+ + pT_- > 1.25\,\mathrm{GeV}$



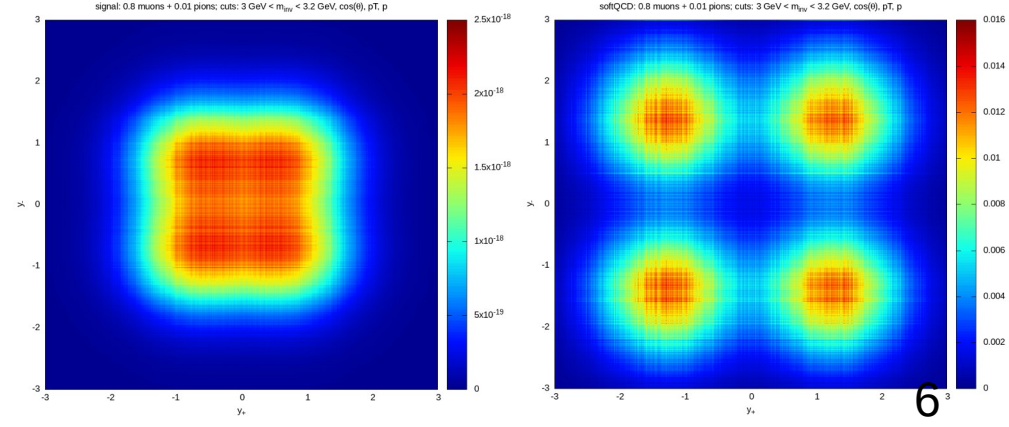
$p_+ + p_- > 2.9\,\mathrm{GeV}$



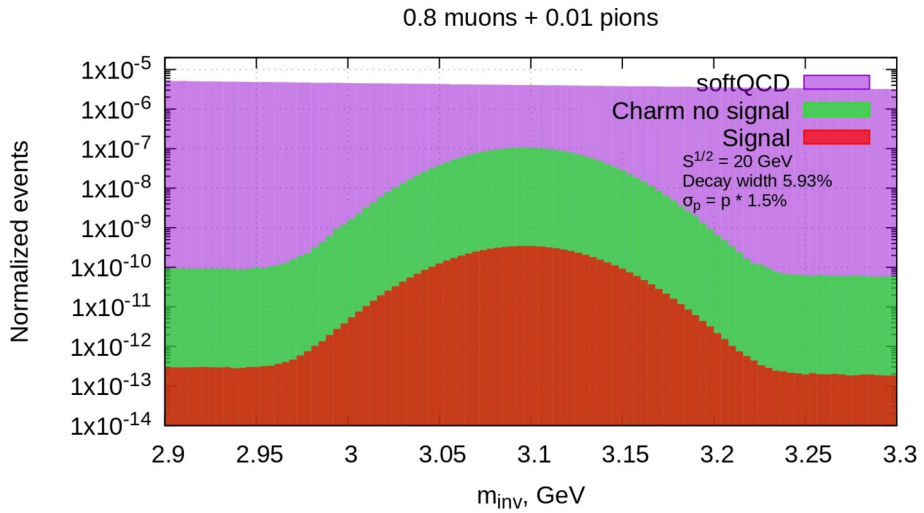
$\left|\cos(\theta_+)\right|^2 + \left|\cos(\theta_-)\right|^2 \leq 1.81$

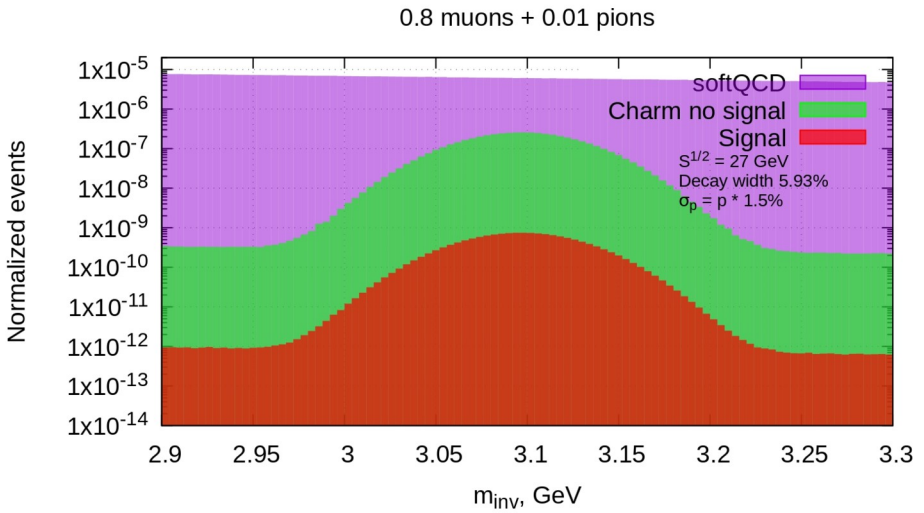


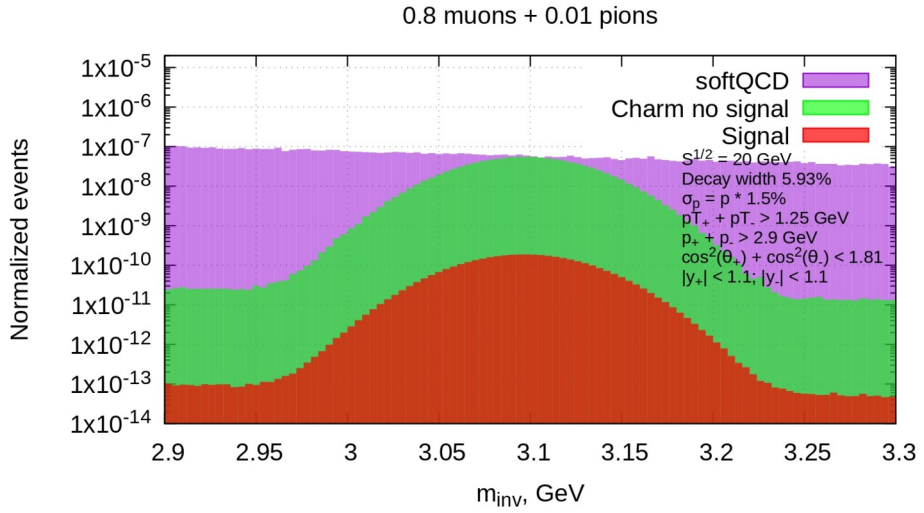
$\left|y_+\right| \leq 1.1; \left|y_-\right| \leq 1.1$

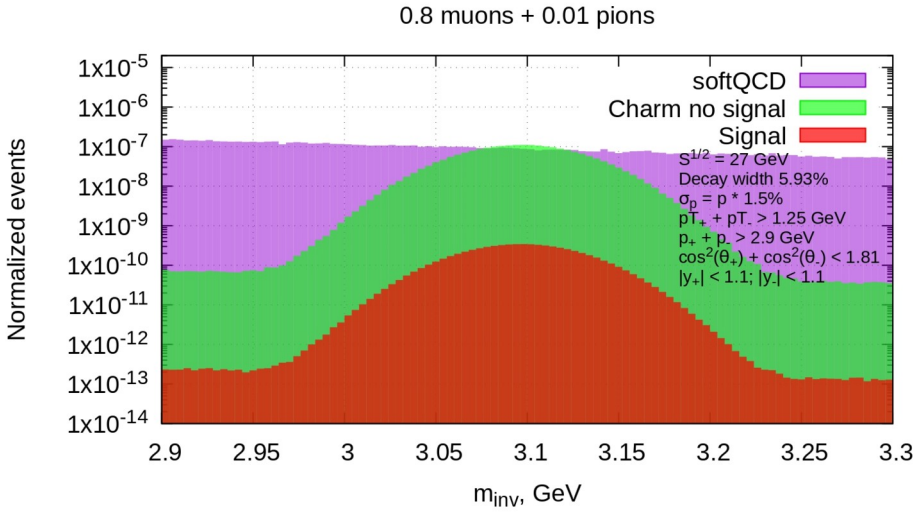


Histograms for 20 and 27 GeV





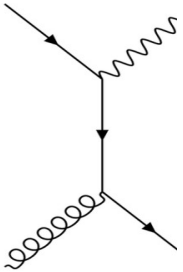




Direct photon production

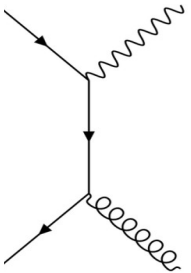
Compton scattering

$g + q \rightarrow \gamma + q$



Annihilation

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



Pythia configuration

Processes:

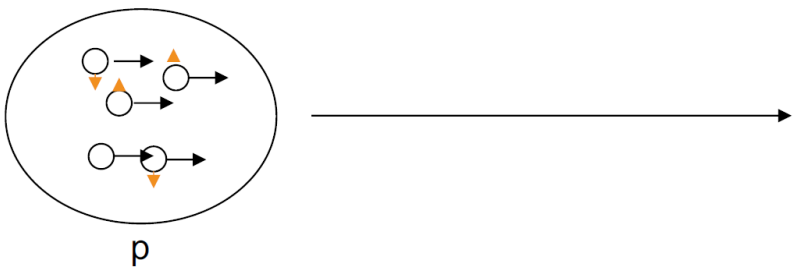
```
pythia.readString("PromptPhoton:qg2qgamma = on");
pythia.readString("PromptPhoton:qqbar2ggamma = on");
```

- *Switch off primordial kT:*

```
pythia.readString("BeamRemnants:primordialKT = off");
```

- *Switch off kT, ISR, FSR:*

```
pythia.readString("BeamRemnants:primordialKT = off");
pythia.readString("PartonLevel:ISR = off");
pythia.readString("PartonLevel:FSR = off");
```

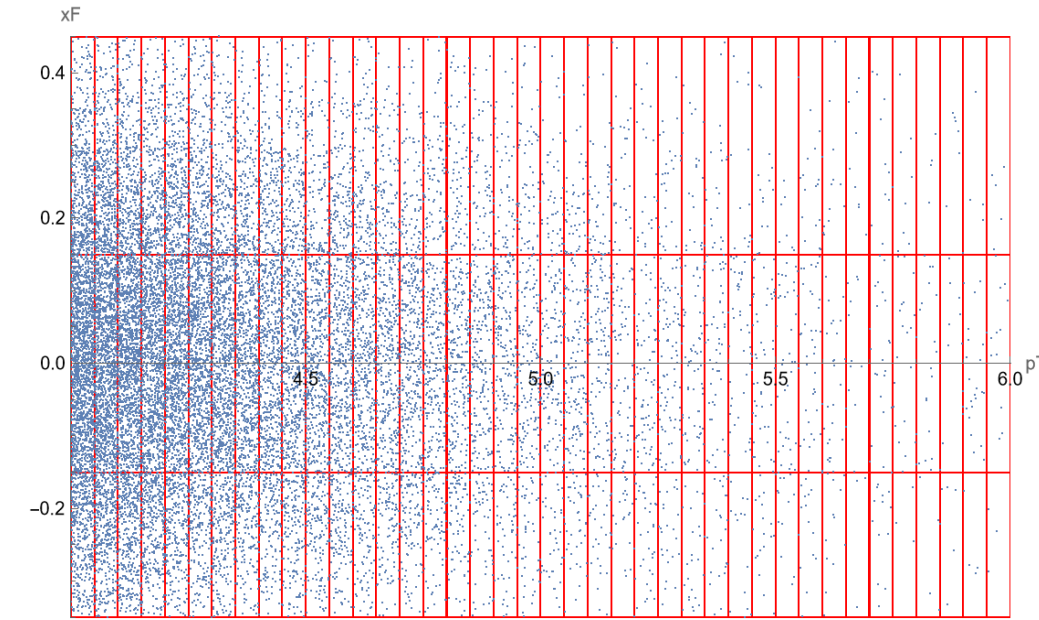


Invariant cross section extraction

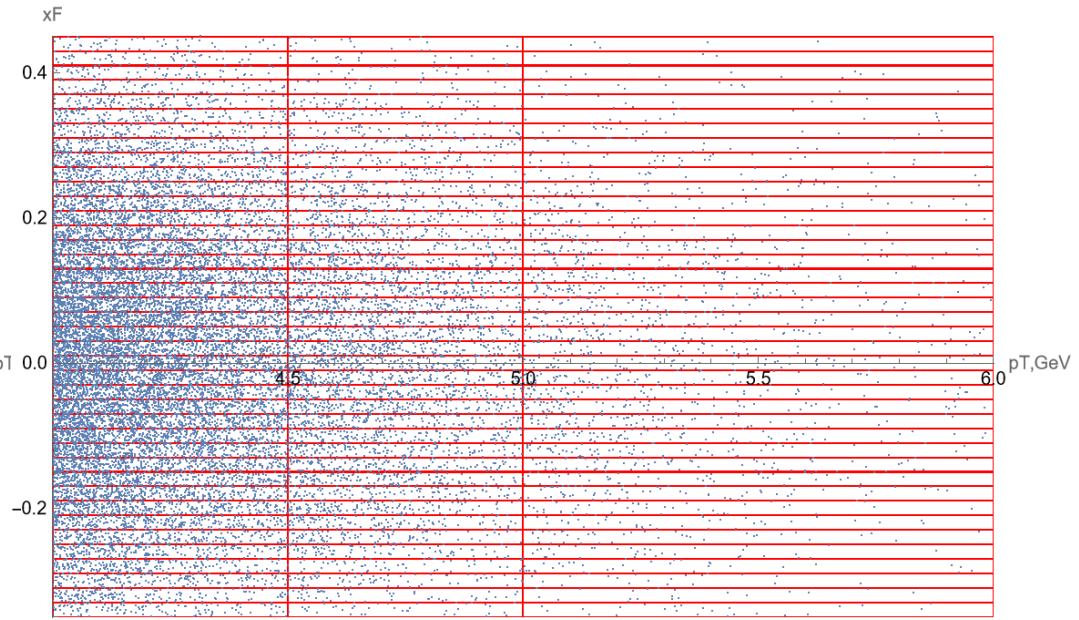
$$E\frac{d^3\sigma}{dp^3}=\frac{\sigma_{total}}{N_{events}}\frac{1}{\pi\sqrt{S}\,\Delta x_F\,\Delta p_T}\sum_{i=1}^{N_0}\frac{E_i}{p_{T,i}}$$

Bin widths for histograms

p_T distributions



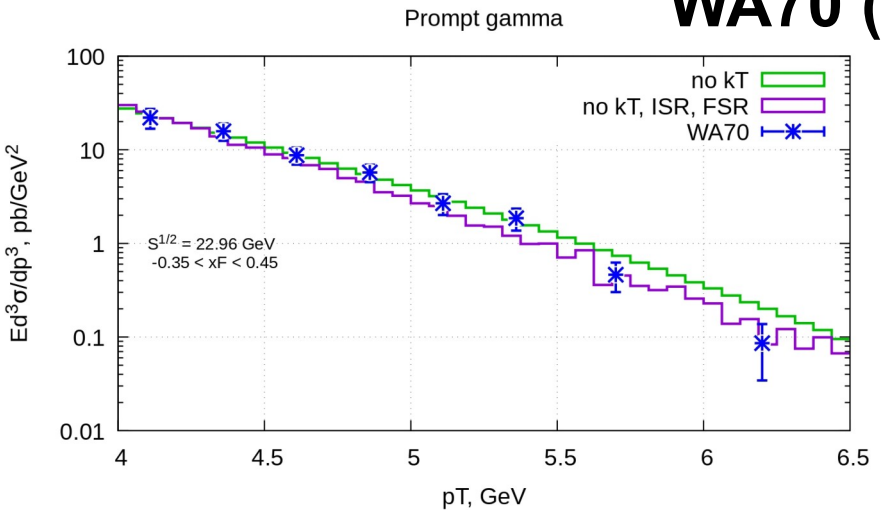
x_F distributions

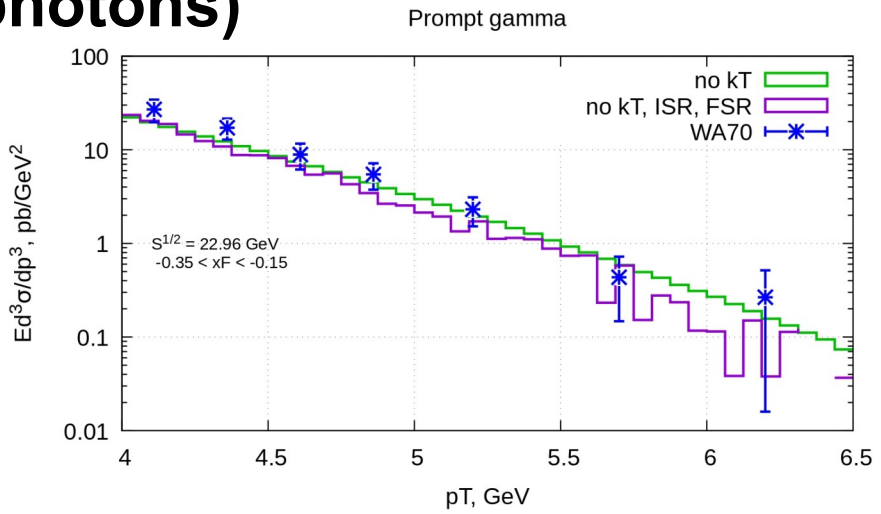


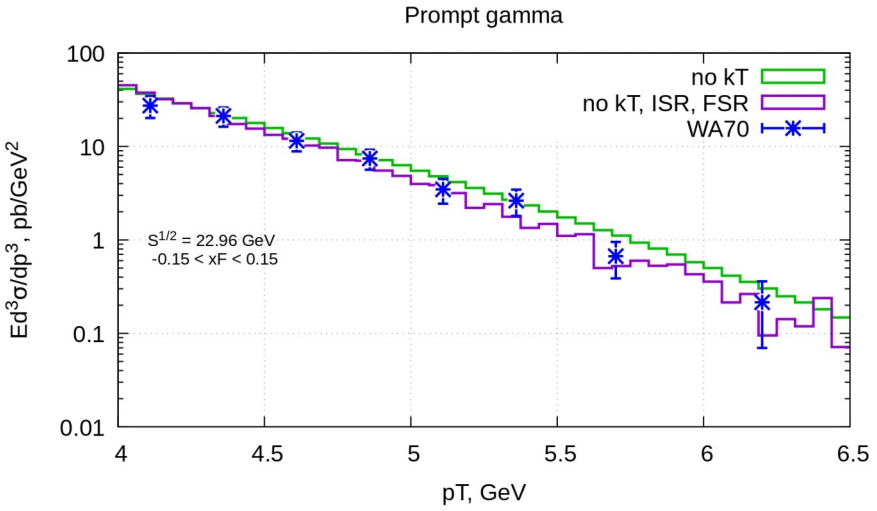
List of experiments

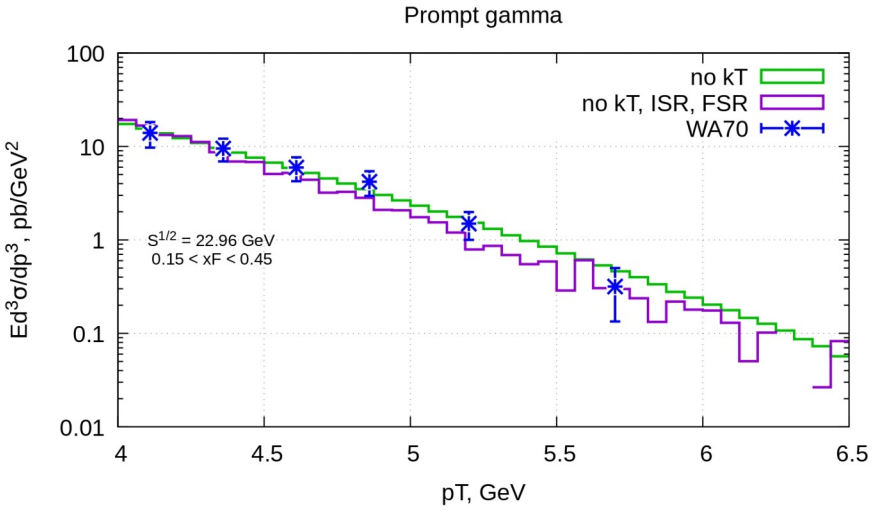
Name	$\sqrt{S}$
E704	19.4 GeV
WA70	22.96 GeV
UA6	24.3 GeV
R806	63.0 GeV

WA70 (photons)



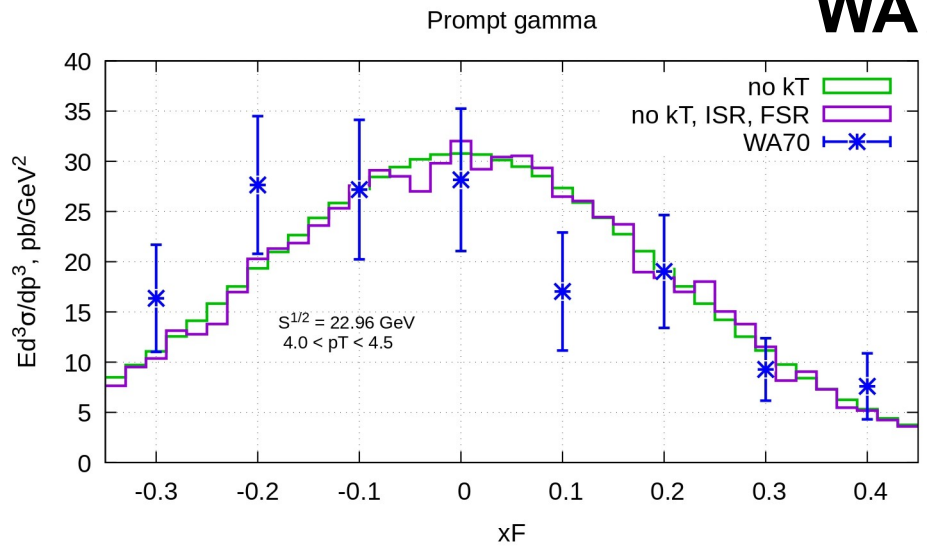


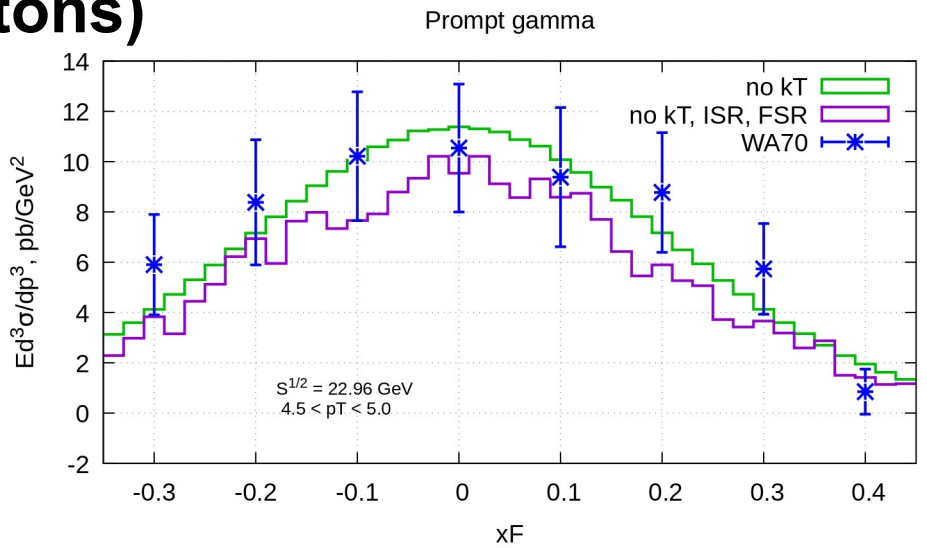


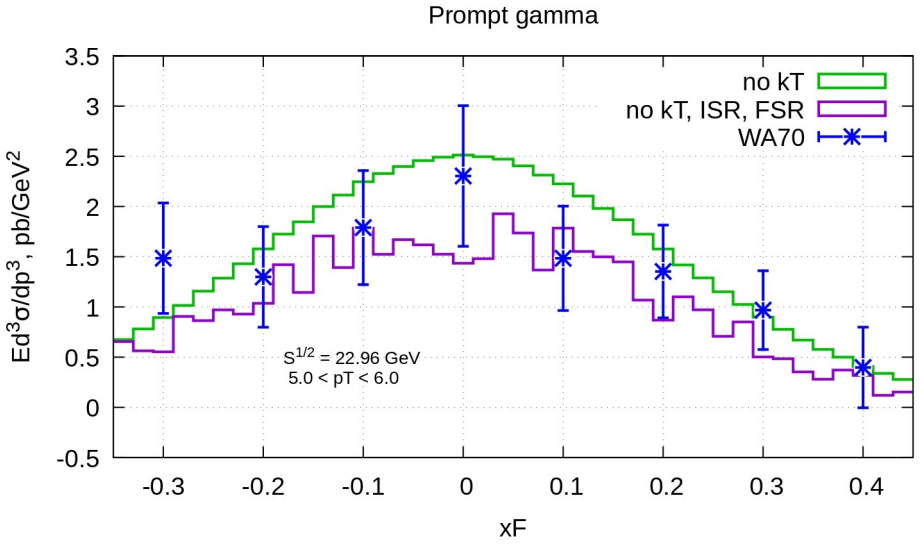


Distribution of photons by p_T in different x_F intervals

WA70 (photons)

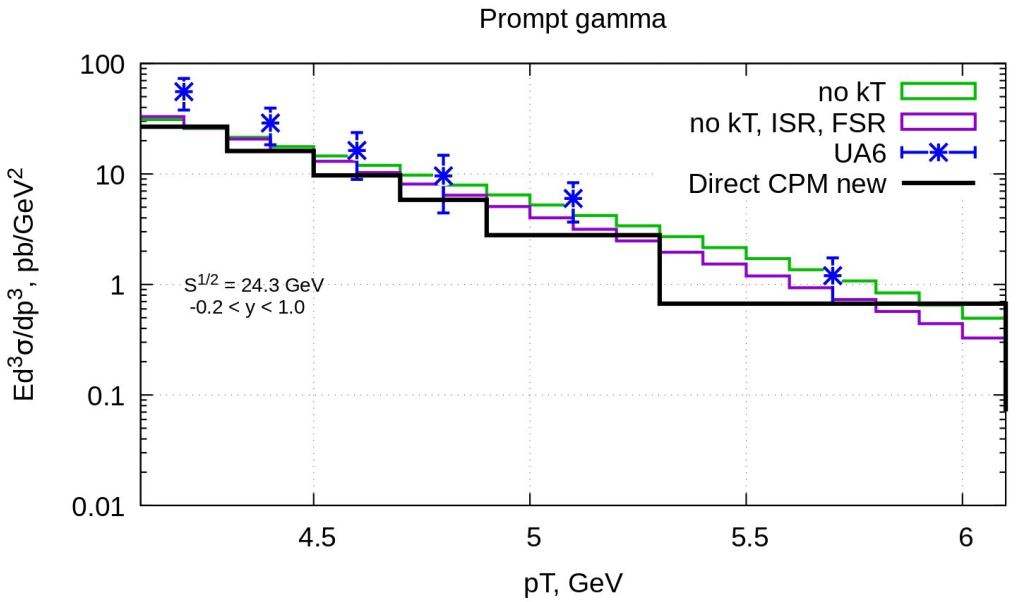


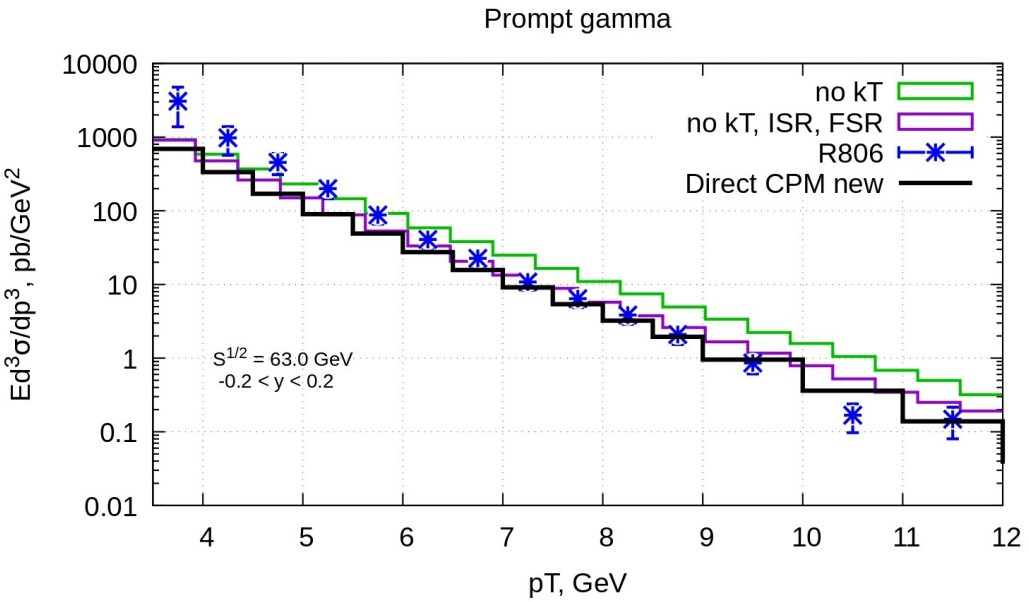




Distribution of photons by x_F in different p_T intervals

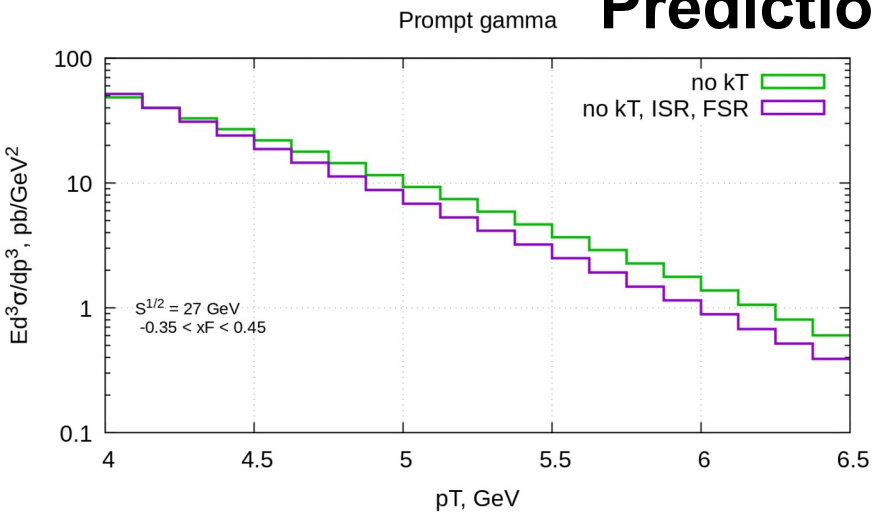
Other experiments

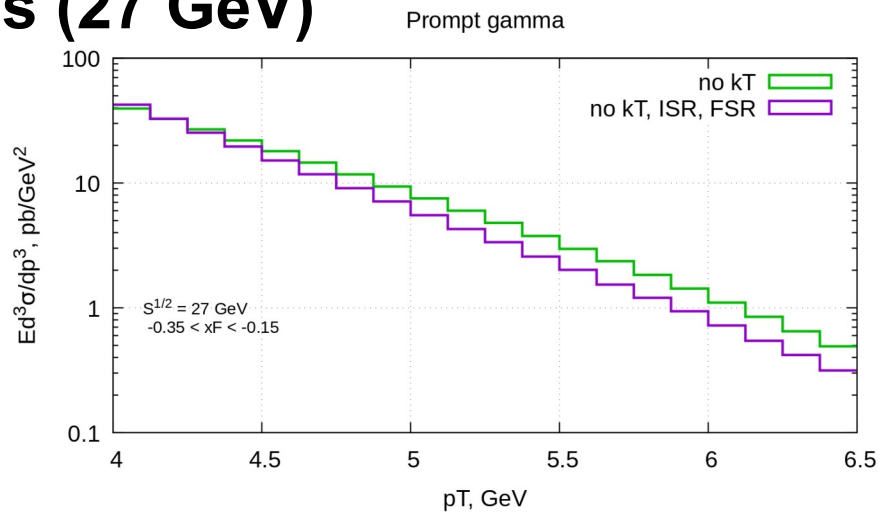


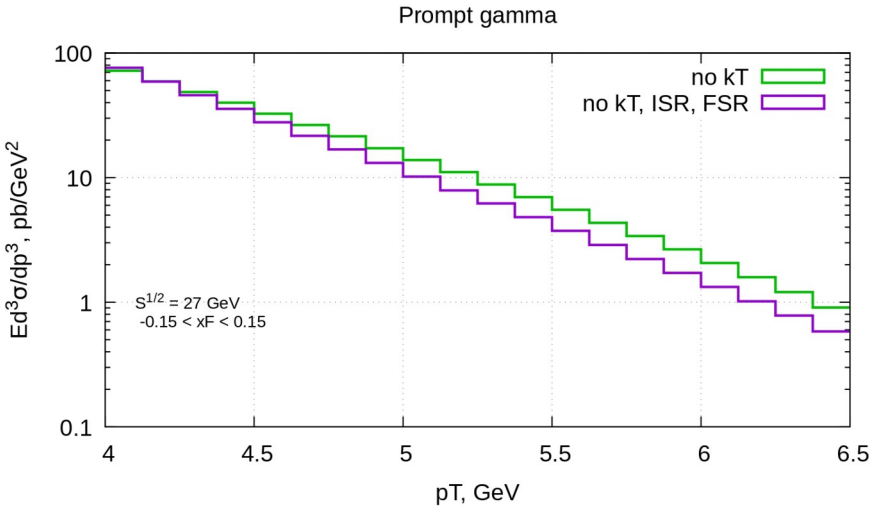


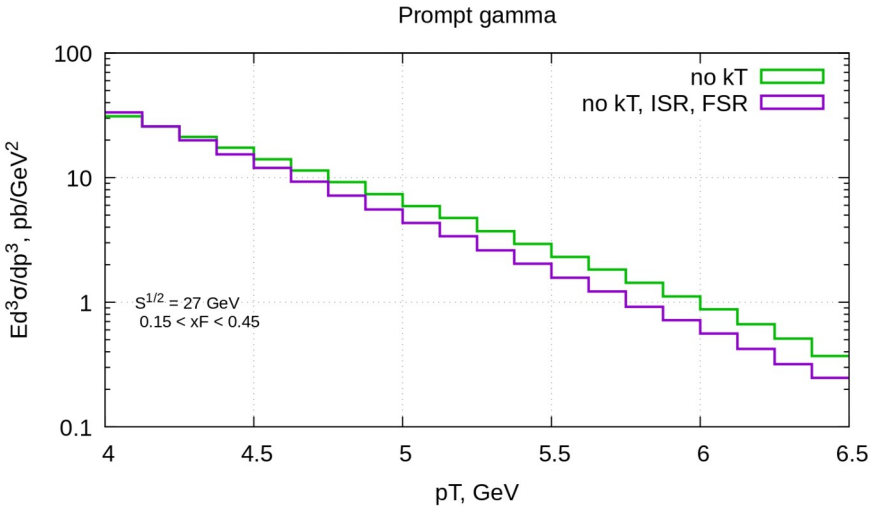
Distribution of photons by p_T

Predictions (27 GeV)



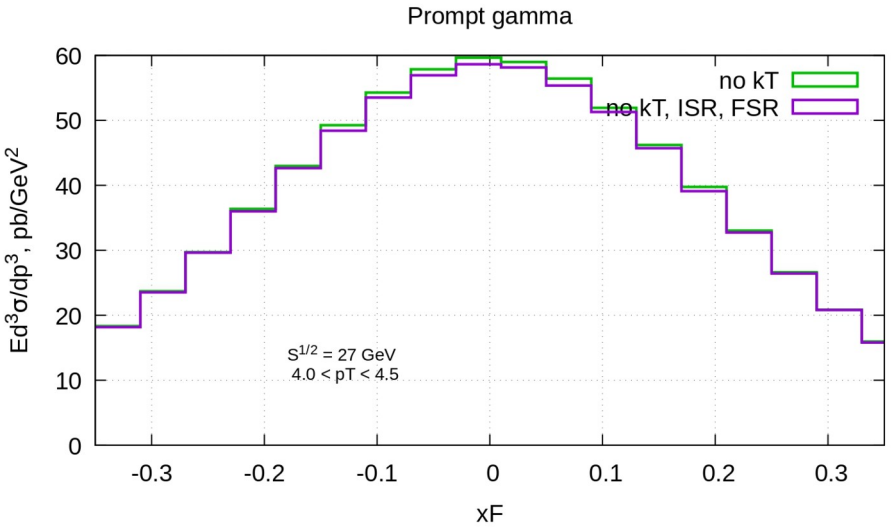


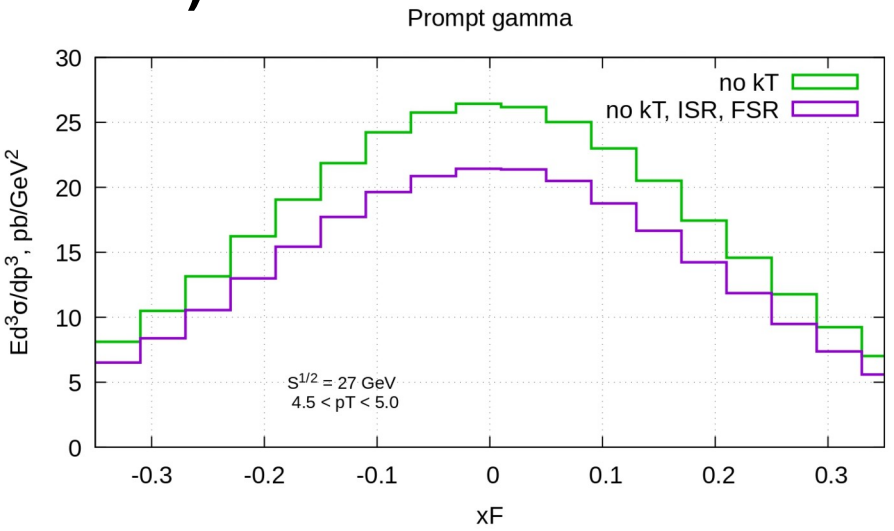


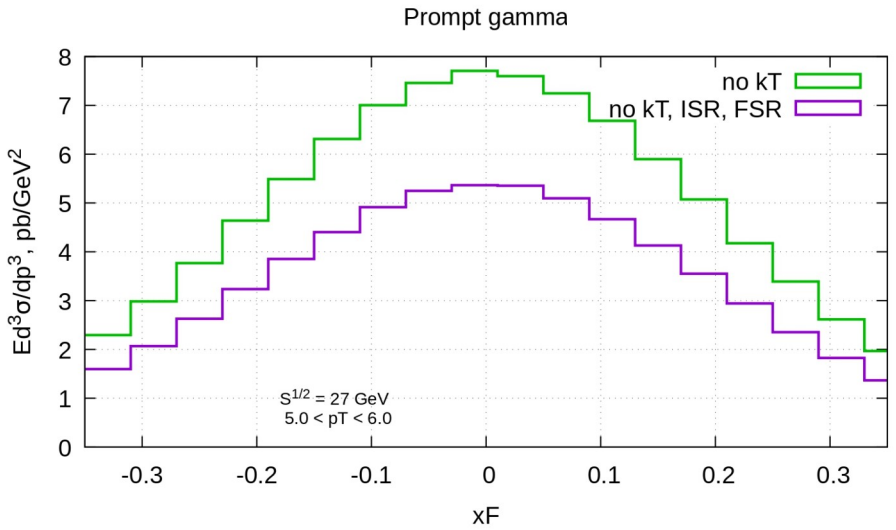


Distribution of photons by p_T in different x_F intervals

Predictions (27 GeV)

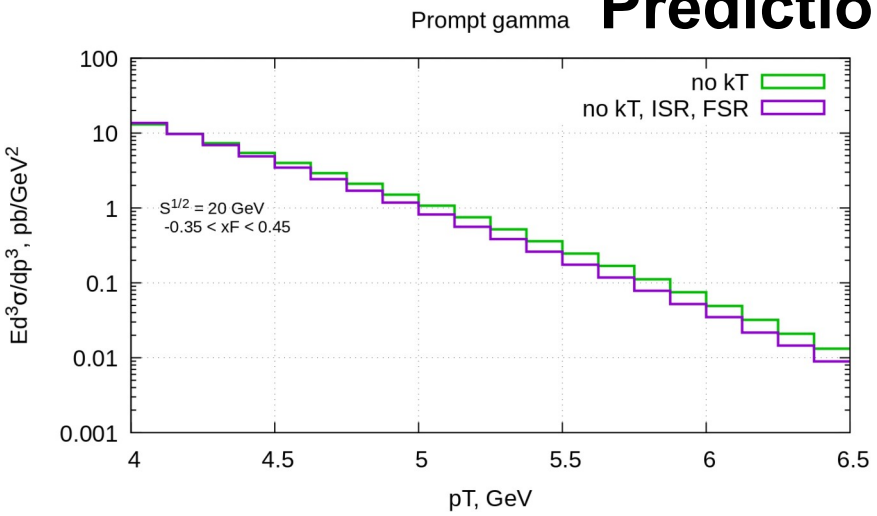


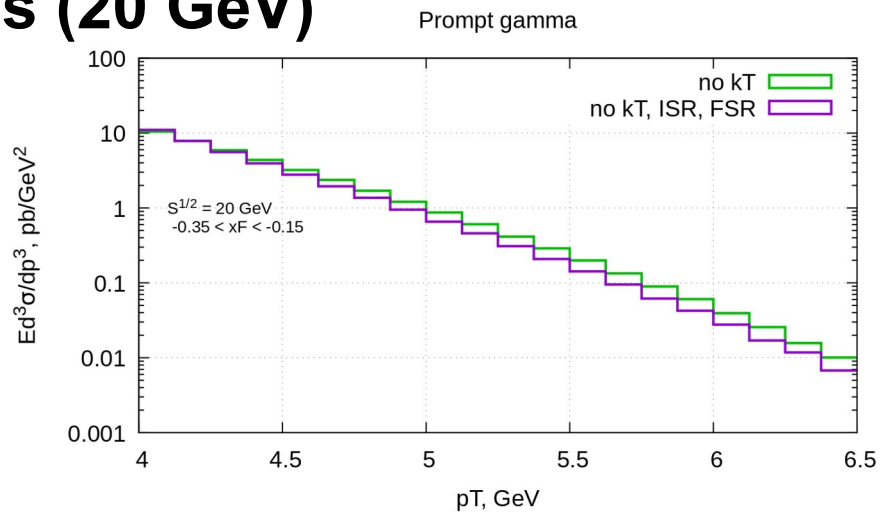


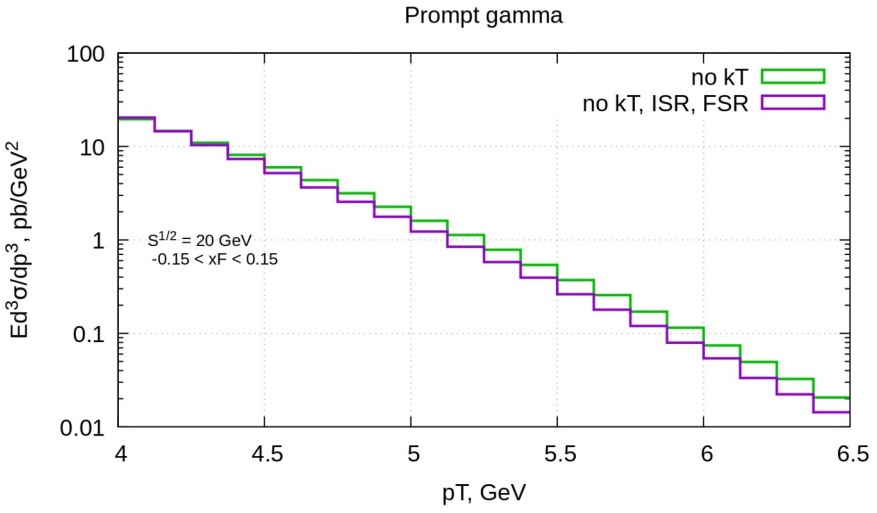


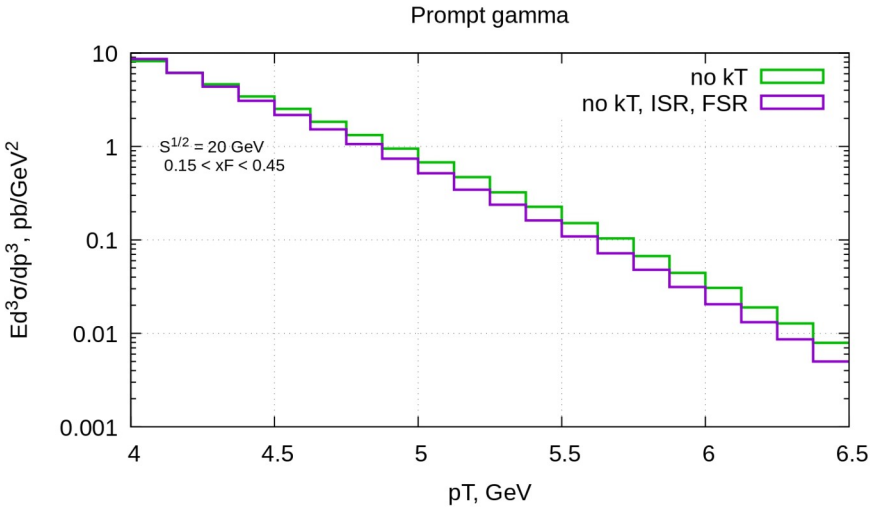
Distribution of photons by x_F in different p_T intervals

Predictions (20 GeV)



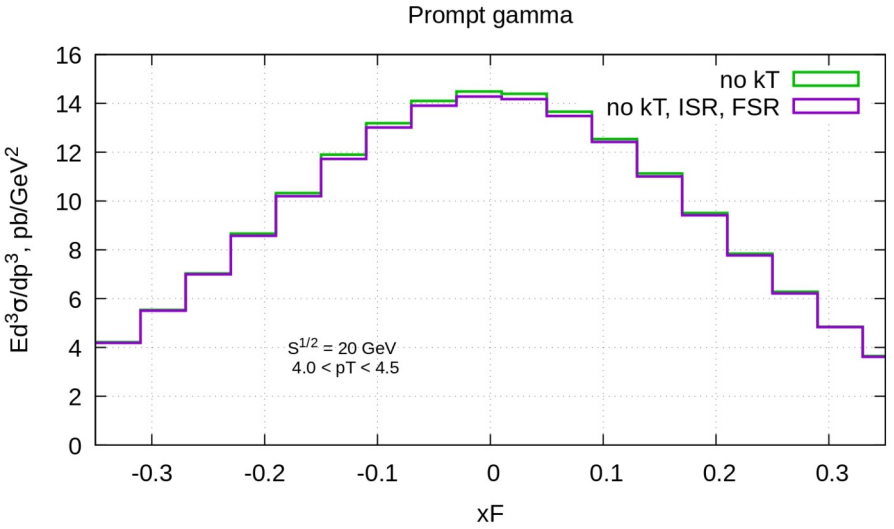


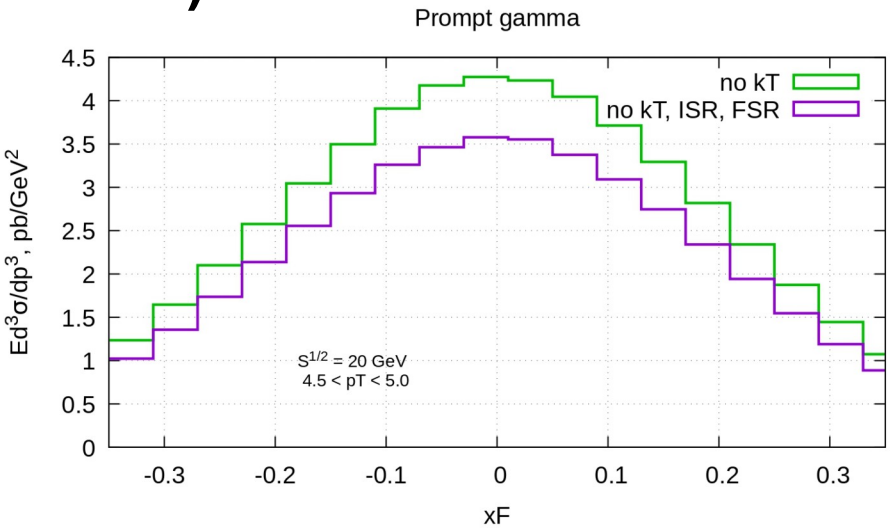


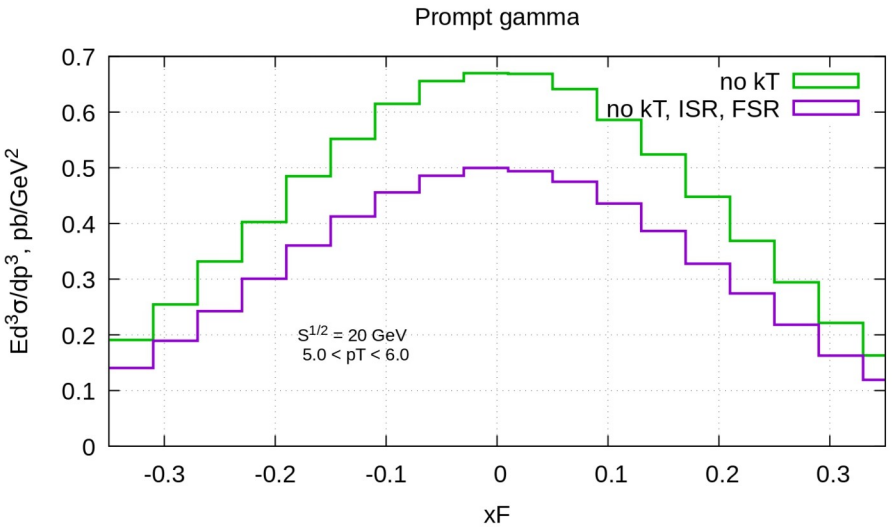


Distribution of photons by p_T in different x_F intervals

Predictions (20 GeV)

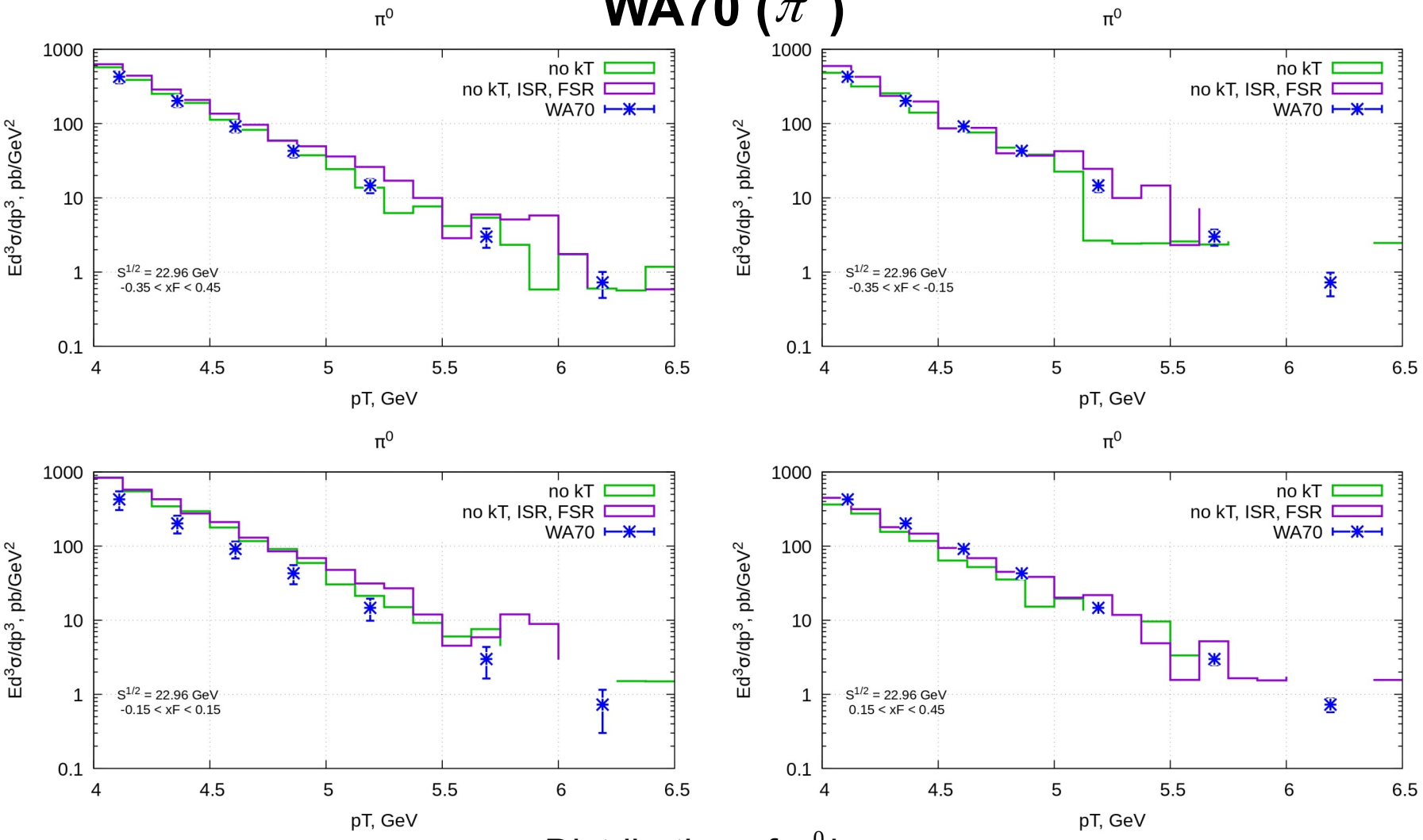






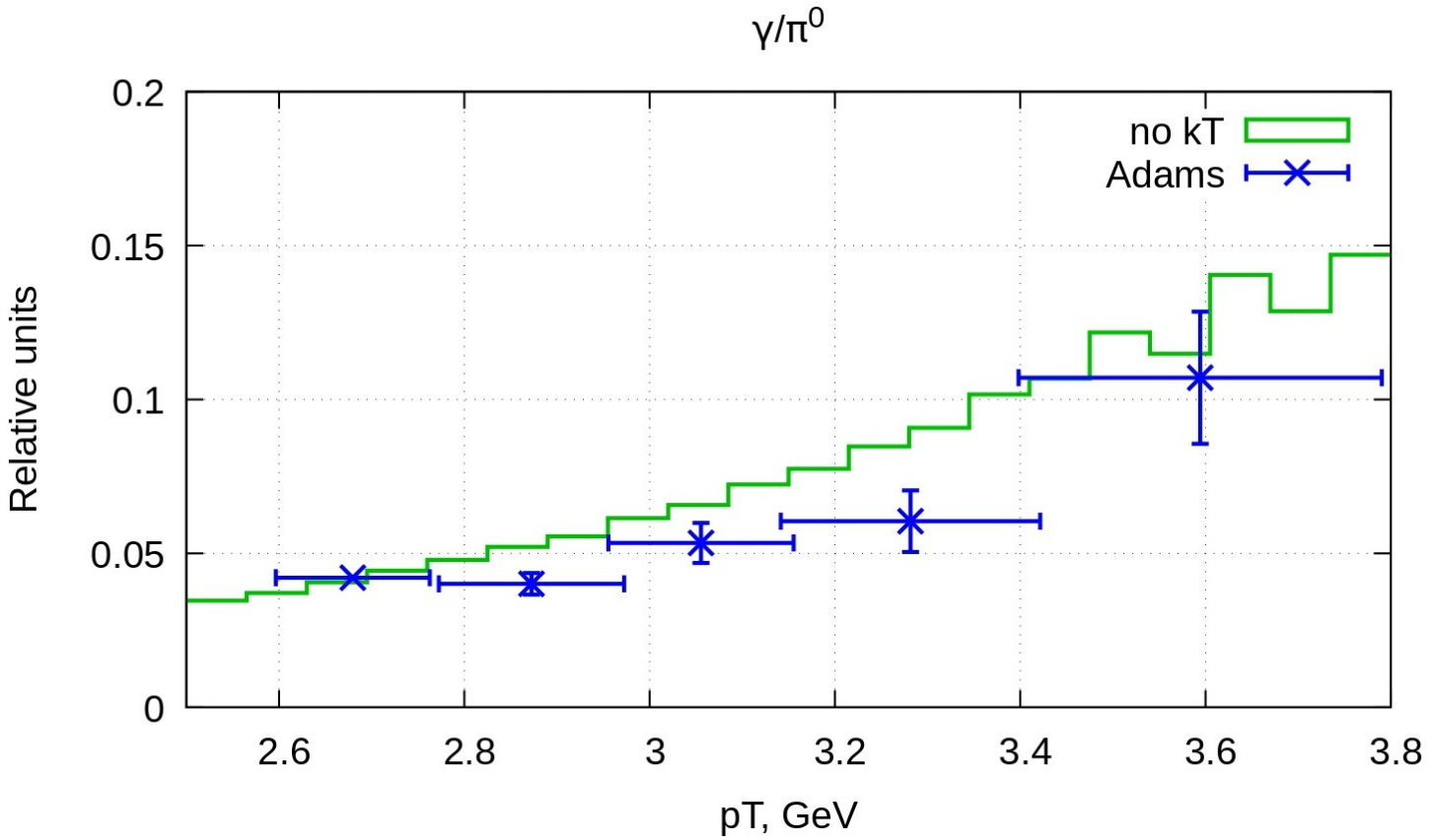
Distribution of photons by x_F in different p_T intervals

WA70 (π^0)



Distribution of π^0 by p_T

Photon to pion ratio



Conclusion and plans

- We found a number of kinematic cuts for the selection of J/ψ meson candidates in a photon associated J/ψ meson production in pp interactions at SPD NICA. We used a $(\mu^+\mu^-)$ decay mode of J/ψ meson taking into account the sensitivity of a real detector.
- The proposed criteria increase the ratio of the number of signal events to background ones in the signal peak region by 42.66 times at the c.m. energy of 27 GeV and 37.21 times at 20 GeV.
- To obtain the correct kinematic cuts on the associated photon at first we studied direct photon production: signal processes and the main source of background photons.
- We found the pythia configuration which leads to a good description of different direct photon experimental data with the set of c.m. energies close to NICA ones. The results are consistent with the LO collinear parton model theoretical calculations.
- The predictions for photon production at NICA energies of 20 and 27 GeV in a number of x_F and p_T regions are presented.
- We simulated the π^0 spectra which are in a satisfactory agreement with existing experimental data, but for higher values of p_T we need more statistics.
- The obtained photon-to-π^0 ratio is consistent with previous measurements.
- Next step is to study the possibility of kinematic cuts on the π^0 decay photons using the similar schem as for J/ψ meson decay muons (see above).

Thank you for your attention