Recent theory and phenomenology results on central-forward di-jets at the LHC

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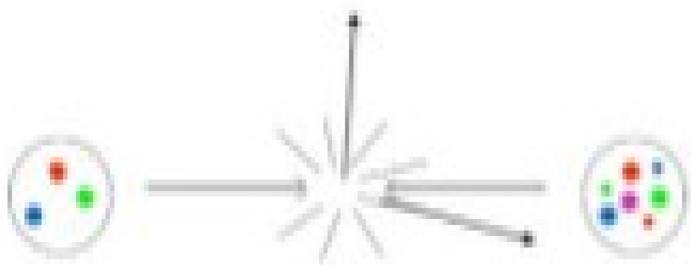
High energy prescription and forward-central di-jets

Deak, Jung, Hautmann Kutak
JHEP 0909:121,2009

$$\frac{d\sigma}{dy_1 dy_2 dp_{1t} dp_{2t} d\Delta\phi} = \sum_{a,c,d} \frac{p_{t1} p_{t2}}{8\pi^2 (x_1 x_2 S)^2} |\mathcal{M}_{ag\to cd}|^2 x_1 f_{a/A}(x_1, \mu^2)\, \mathcal{F}_{g/B}(x_2, k^2) \frac{1}{1+\delta_{cd}}$$

$S = 2P_1 \cdot P_2$



- Resummation of logs of x and logs of hard scale
- Knowing well pdf at large x one can get information about low x physics
- Framework goes recently under name "hybride framework"

$$x_1 = \frac{1}{\sqrt{S}}\left(p_{t1} e^{y_1} + p_{t2} e^{y_2}\right) \xrightarrow{y_1 \sim 0,\, y_2 \gg 0} \sim 1$$

$$x_2 = \frac{1}{\sqrt{S}}\left(p_{t1} e^{-y_1} + p_{t2} e^{-y_2}\right) \qquad \ll 1$$

$$k_1^\mu = x_1 P_1^\mu$$
$$k_2^\mu = x_2 P_2^\mu + k_t^\mu$$

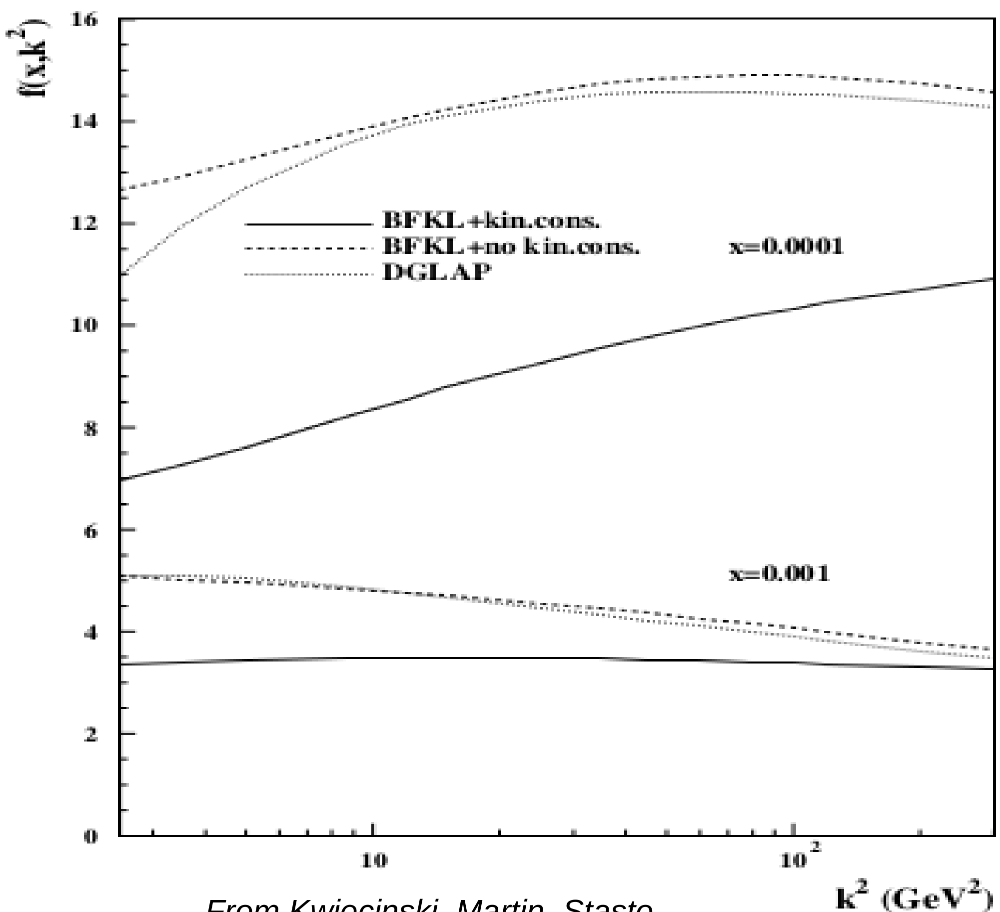
BFKL with subleading corrections Kwiecinski, Martin, Staśto prescription

Nonsingular pieces of splitting function

Kinematical effects i.e. Momentum of gluon dominated by it's transversal component

Running coupling

In principle not applicable to final states since no hard scale dependence

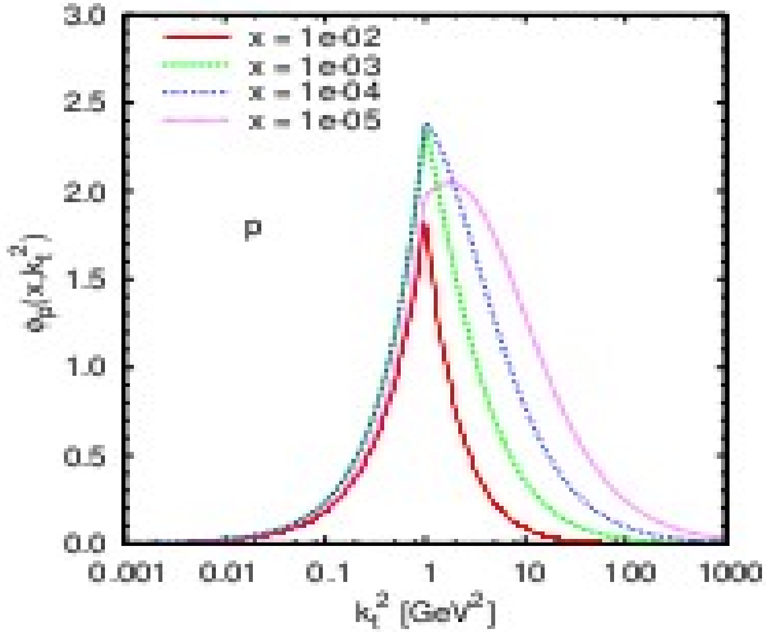


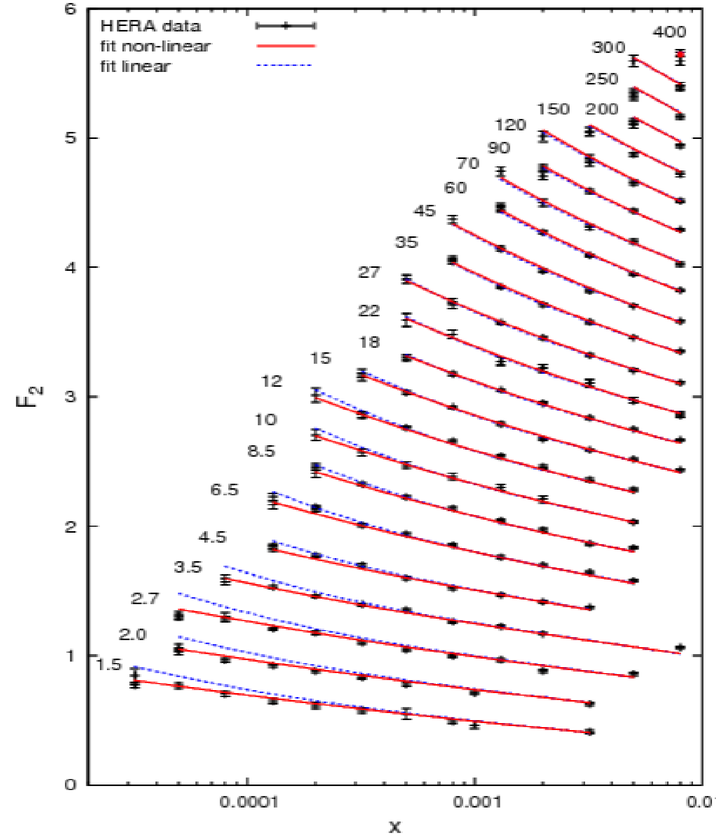
From Kwiecinski, Martin, Stasto
Phys.Rev. D56 (1997) 3991-4006

$$f(x,k^2) = k^2\mathcal{F}(x,k^2)$$

$$\mathcal{F}_p(x,k^2) = \mathcal{F}_p^{(0)}(x,k^2) + \frac{\alpha_s(k^2)N_c}{\pi}\int_x^1 \frac{dz}{z}\int_{k_0^2}^{\infty}\frac{dl^2}{l^2}\left\{\frac{l^2\mathcal{F}_p(\frac{x}{z},l^2)\,\theta(\frac{k^2}{z}-l^2) - k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|l^2-k^2|} + \frac{k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|4l^4+k^4|^{\frac{1}{2}}}\right\} + \frac{\alpha_s(k^2)}{2\pi k^2}\int_x^1 dz\left(P_{gg}(z)-\frac{2N_c}{z}\right)\int_{k_0^2}^{k^2} dl^2\,\mathcal{F}_p(\frac{x}{z},l^2)$$

Unintegrated gluon density from BK with corrections





$$
\begin{aligned}
\mathcal{F}_p(x,k^2) \;=\; & \mathcal{F}_p^{(0)}(x,k^2) \\
& + \frac{\alpha_s(k^2)N_c}{\pi}\int_x^1 \frac{dz}{z}\int_{k_0^2}^{\infty}\frac{dl^2}{l^2}\left\{\frac{l^2\mathcal{F}_p(\frac{x}{z},l^2)\,\theta(\frac{k^2}{z}-l^2) - k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|l^2-k^2|} + \frac{k^2\mathcal{F}_p(\frac{x}{z},k^2)}{|4l^4+k^4|^{\frac{1}{2}}}\right\} \\
& + \frac{\alpha_s(k^2)}{2\pi k^2}\int_x^1 dz\left(P_{gg}(z) - \frac{2N_c}{z}\right)\int_{k_0^2}^{k^2} dl^2\,\mathcal{F}_p(\frac{x}{z},l^2) \\
& - \frac{2\alpha_s^2(k^2)}{R^2}\left[\left(\int_{k^2}^{\infty}\frac{dl^2}{l^2}\mathcal{F}_p(x,l^2)\right)^2 + \mathcal{F}_p(x,k^2)\int_{k^2}^{\infty}\frac{dl^2}{l^2}\ln\left(\frac{l^2}{k^2}\right)\mathcal{F}_p(x,l^2)\right]
\end{aligned}
$$

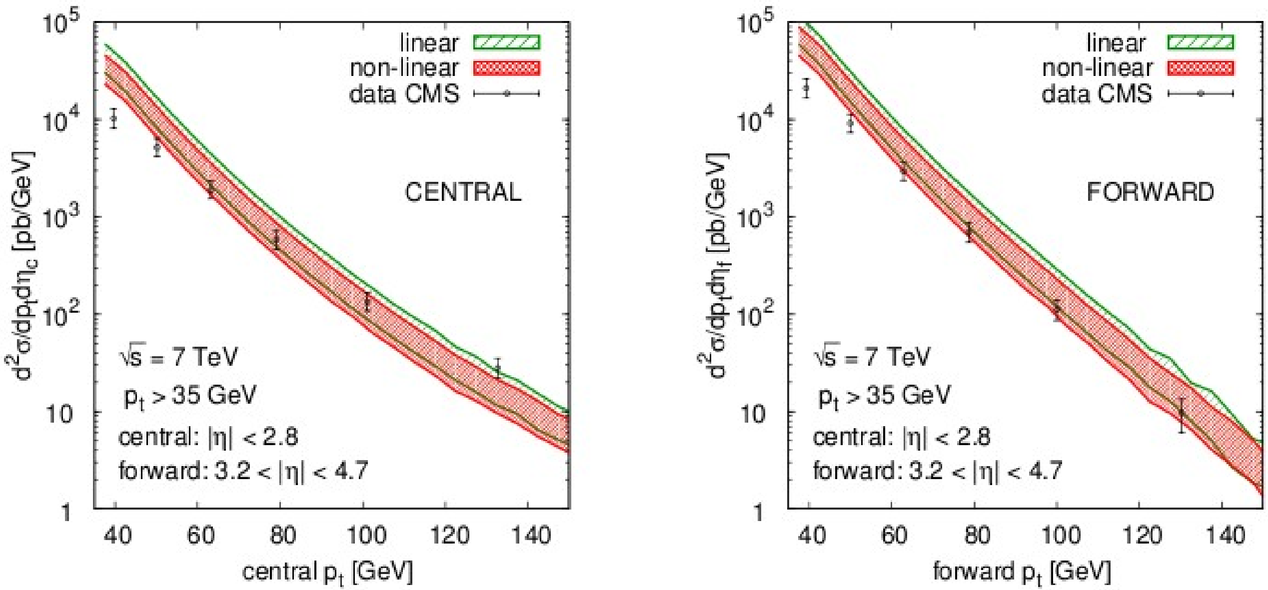
Kwiecinski, KK '03

Corrections
of higher orders
Included.
Kin. Constr
DGLAP spf

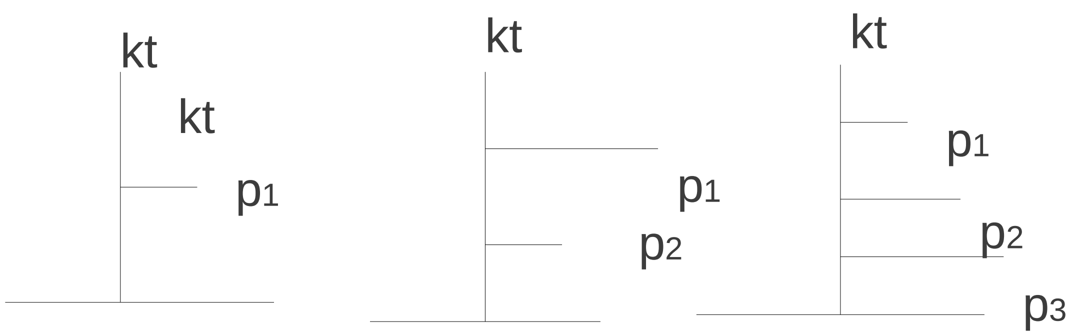
Andersson, Gustafson,Sammuelsson '96
Kwiecinski, Martin, Stasto '96,

Di-jets p_t spectra

S.Sapeta. KK ,12



Reasonable agreement.



Gluon emissions are unordered in pt and udd up to $k_t = |p_1+p_2+.....p_n|$

During evolution time incoming gluon becomes off-shell

Crucial effect of higher order corrections

Final states via Sudakov effects - illustration

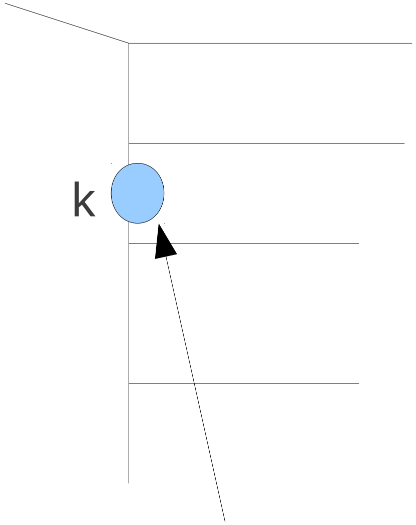
Motivated by
KMR prescription

Probability of finding no real gluon
Between scales kt and μ

$$\overline{\mathcal{O}} = \frac{\sigma}{\overline{W}} \left[\sum_i w_i \Delta\left(\mu_i, k_{Ti}\right) F_i^{\mathcal{O}}\left(X_i\right) \Theta\left(\mu_i > k_{Ti}\right) + \frac{\widetilde{W}}{W} \sum_j w_j F_j^{\mathcal{O}}\left(X_j\right) \Theta\left(k_{Tj} > \mu_j\right) \right]$$

$$\overline{W} = \sum_i w_i \Delta\left(\mu_i, k_{Ti}\right) \Theta\left(\mu_i > k_{Ti}\right) + \frac{\widetilde{W}}{W} \sum_j w_j \Theta\left(k_{Tj} > \mu_j\right)$$

$$\widetilde{W} = \sum_i w_i \Delta\left(\mu_i, k_{Ti}\right) \Theta\left(\mu_i > k_{Ti}\right) + \sum_j w_j \Theta\left(k_{Tj} > \mu_j\right)$$



μ hard scale

$$\Delta\left(\mu, k_T^2\right) = \exp\left(- \int_{k_T^2}^{\mu^2} \frac{dk_T'^2}{k_T'^2} \frac{\alpha_s\left(k_T'^2\right)}{2\pi} \sum_i \int_0^{1-\epsilon\left(k_T', \mu\right)} dz \, P_{ig}\left(z\right) \right)$$

σ *total cross section*

$W = \sum_i w_i$ *total weight*

$F_i^{\mathcal{O}}$ *functon defining observable*

Survival probability of the gap without emissions

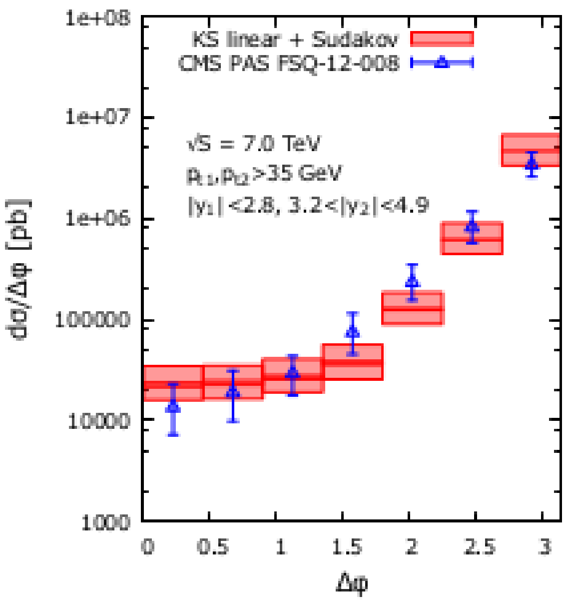
Kimber, Martin, Ryskin framework '01

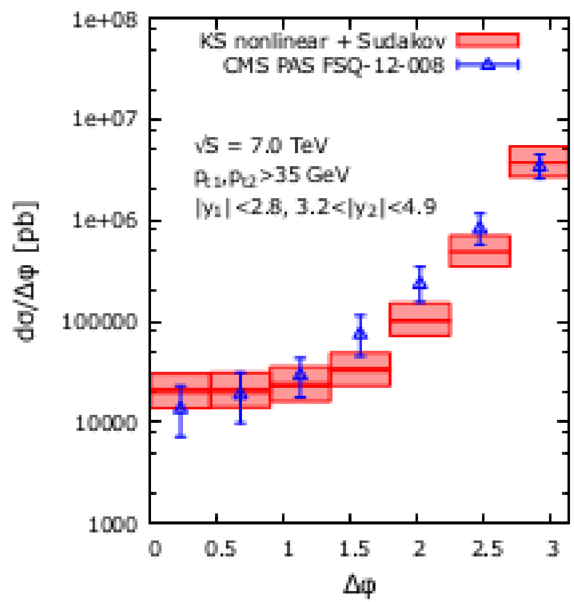
Tools to be used

- *General tool for matrix elements within HEF based on spinor helicity method (A. van Hameren)*
- *Gauge link based tool to evaluate matrix elements (OGIME P. Kotko)*
- *Monte Carlo for production of dijets, trijets within HEF LxJet (P. Kotko)*
- *Tool for forward dijets Forward (S. Sapeta)*

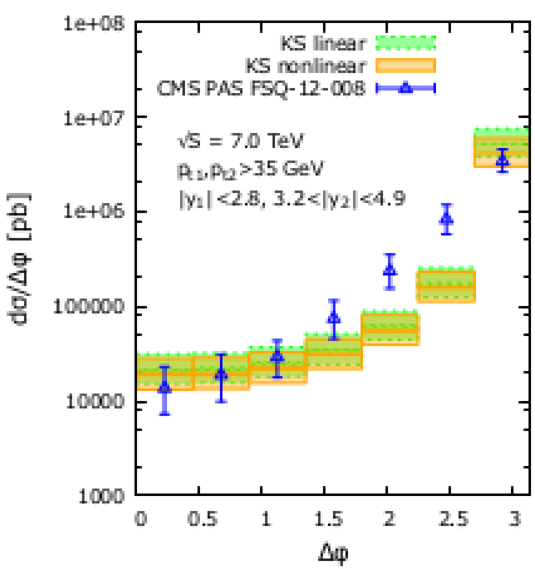
Decorelations inclusive scenario

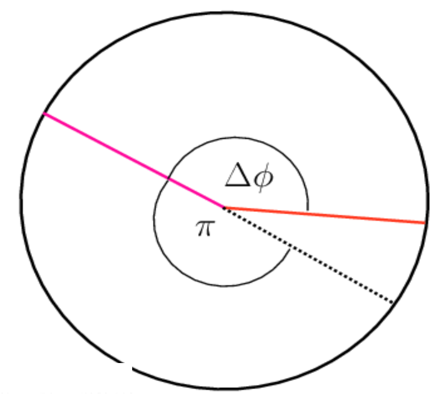
A.v.Hameren, P.Kotko, KK, S.Sapeta '14





pt1,pt2 >35, leading jets
|y1|<2.8, 3.2<|y2|<4.7
No further requirement on jets





In DGLAP approach
i.e 2 →2 + pdf one would
Get delta function at

$$\Delta\phi = \pi$$

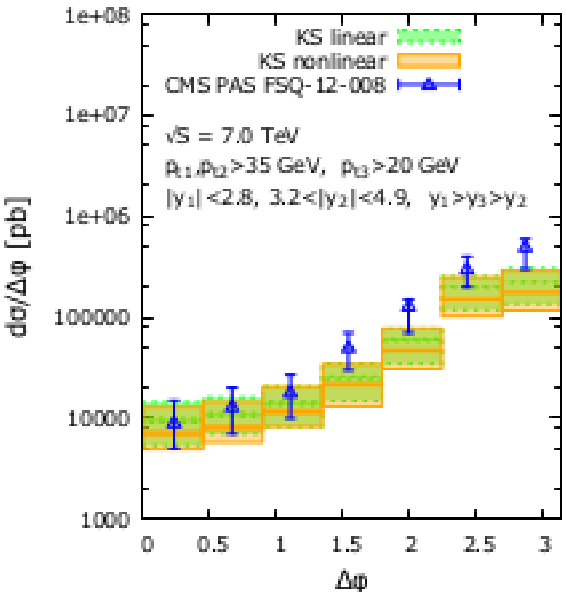
Sudakov effects by reweighting implemented in LxJet Monte Carlo P. Kotko

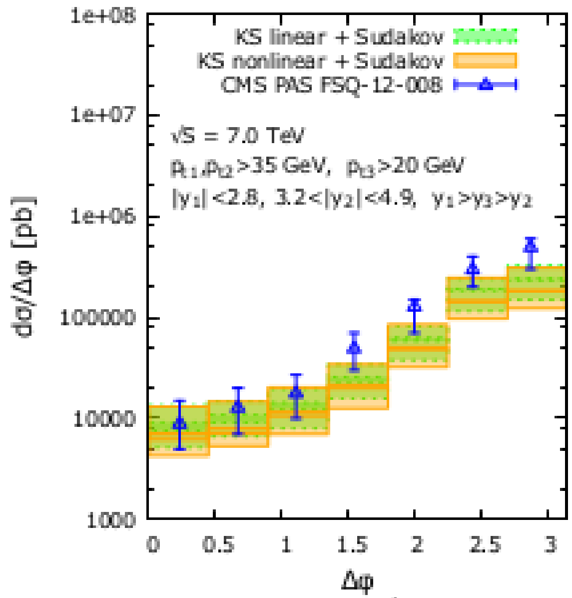
Observable suggested to study BFKL effects
Sabio-Vera, Schwensen '06

Studied also context of RHIC
Albacete, Marquet '10

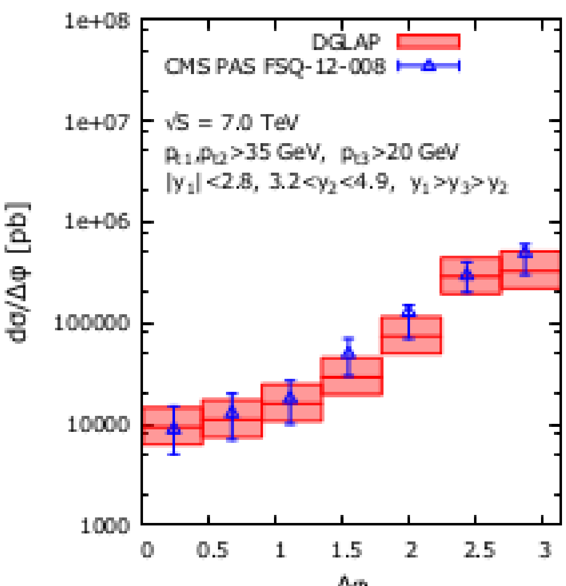
Decorelations inside jet tag scenario

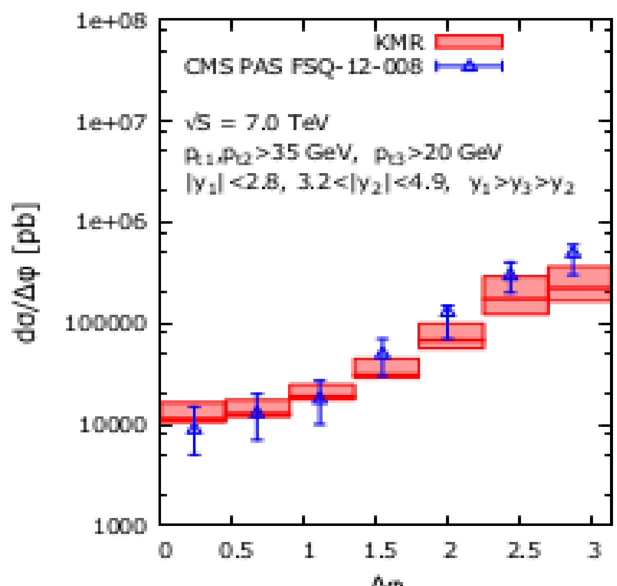
A.v.Hameren, P.Kotko, KK, S.Sapeta '14

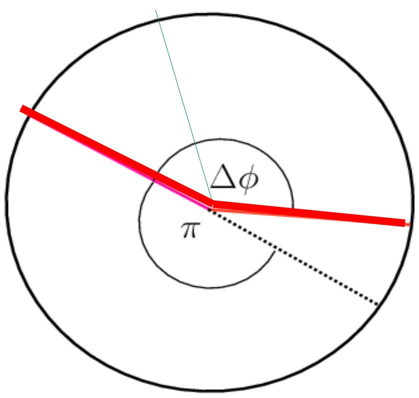




pt1, pt2 >35 GeV, leading jets |y1|<2.8, 3.2<|y2|<4.7 Third jet pt>20GeV. Between the forward and central region



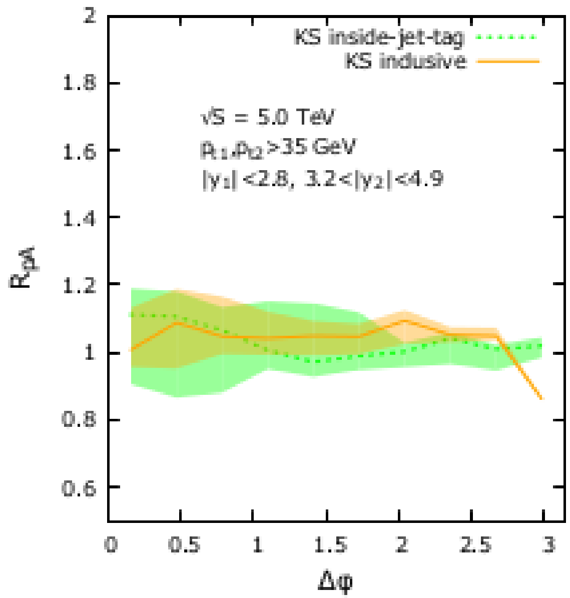


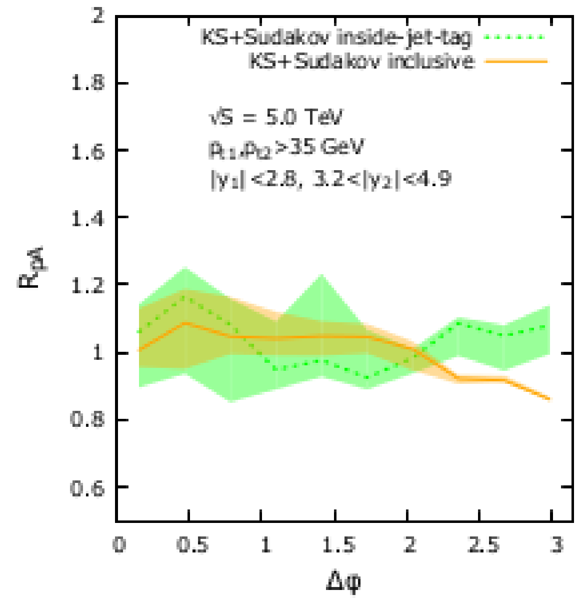


Sudakov effects by reweighting implemented in LxJet Monte Carlo P. Kotko

Predictions for p-Pb

A.v.Hameren, P.Kotko, KK, S.Sapeta '14



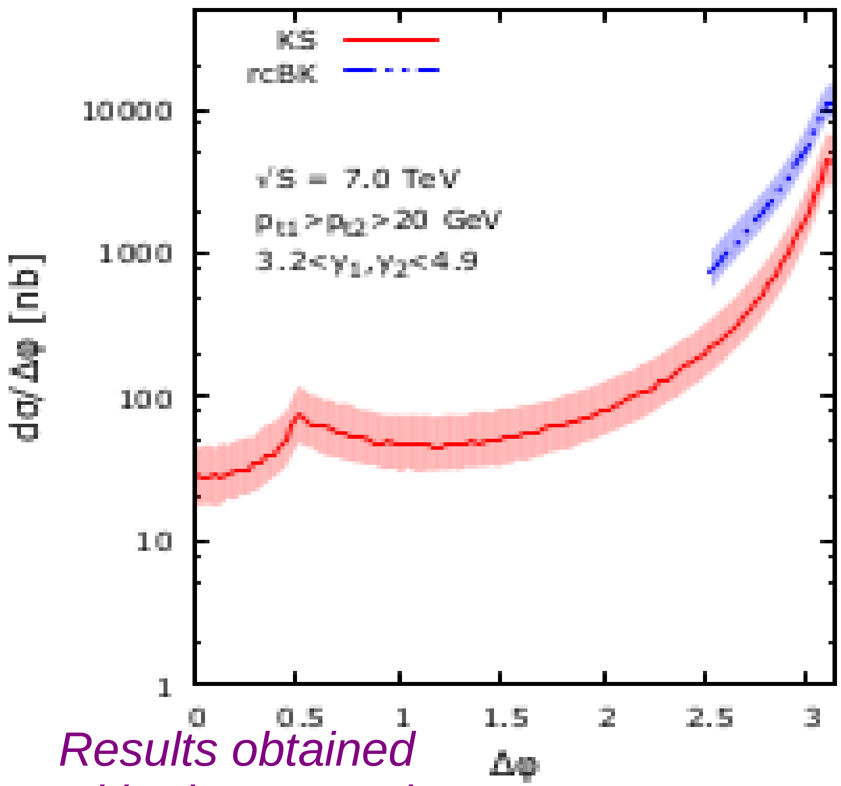


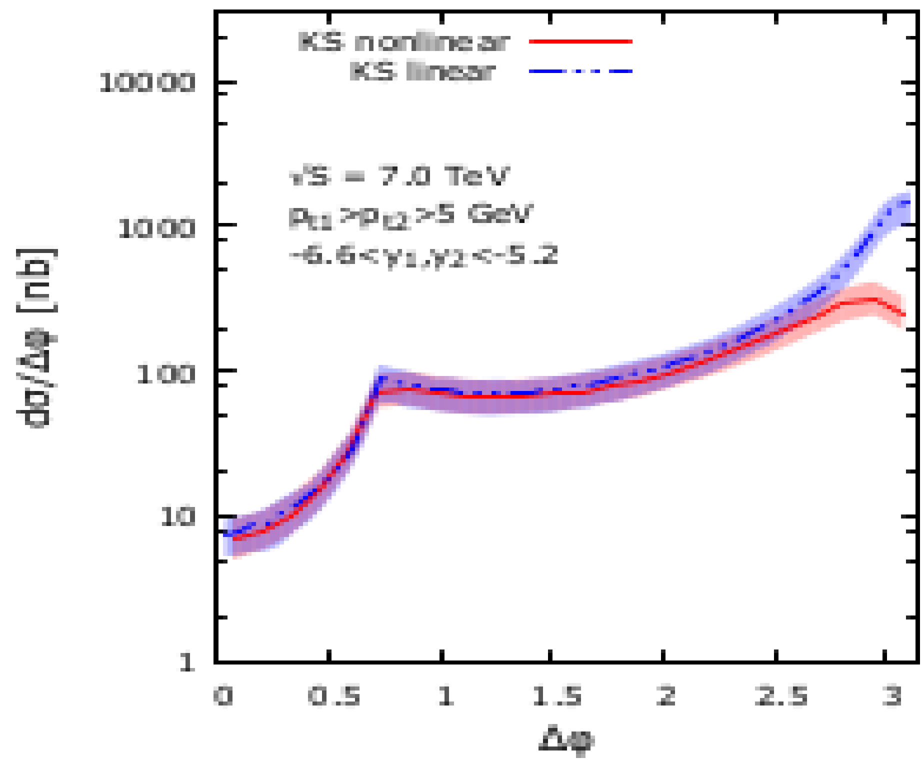
- *Sudakov enhance saturation effects*
- *Hawever, satuartion effects are rather weak*

Forward-forward di-jets

Results for decorelations

Van Hameren, Kotko, KK ,Marquet, Sapeta' 13



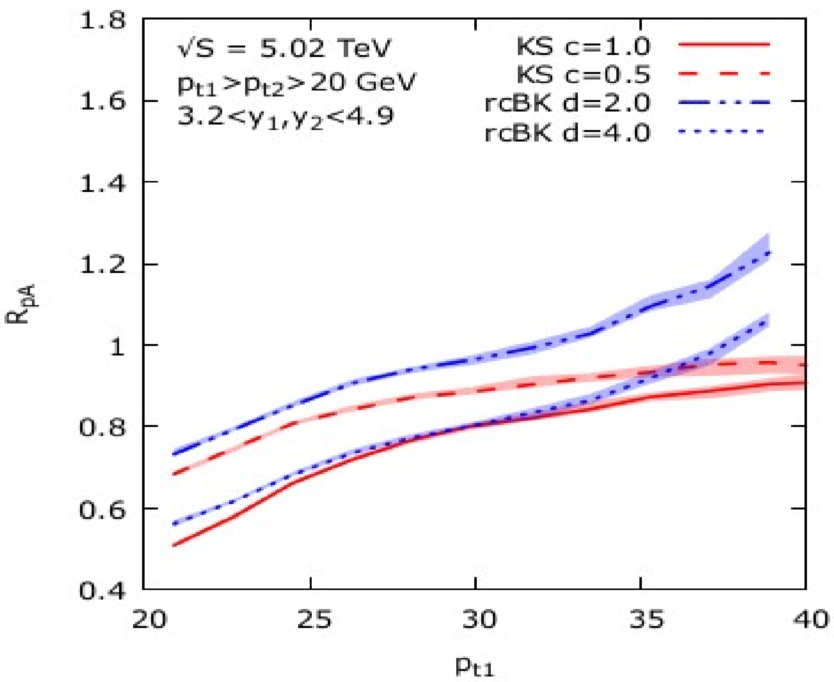


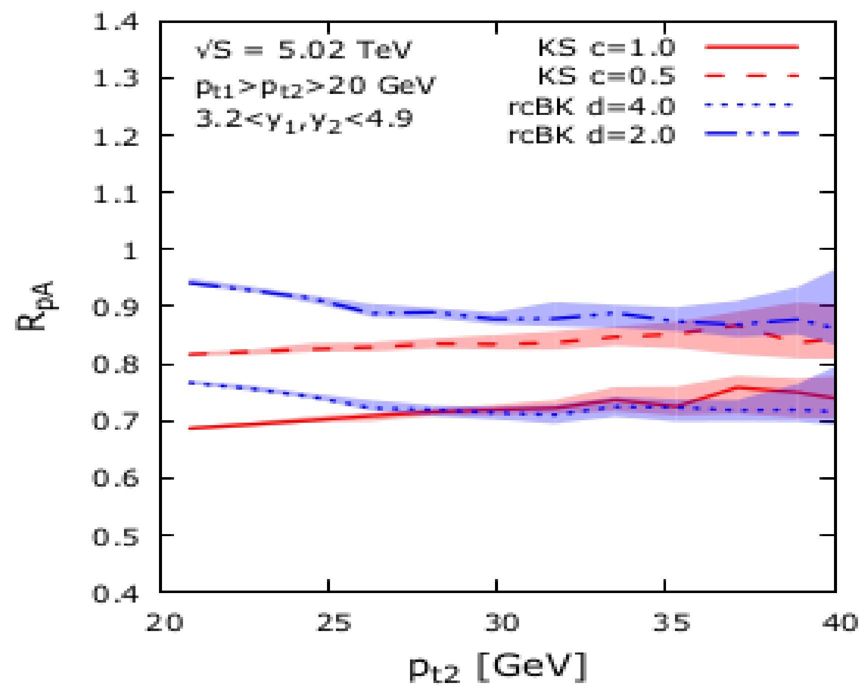
Results obtained with gluons coming from rcBK and BK with corrections of higher orders

Importance of corrections of higher orders

Forward-forward di-jets

A. van Hameren:,KK, Kotko,Marquet, Sapeta '14





Studies of subleading jet gives more pronounced signal of suppression. Details of that are still to be understood

Conclusions

- *Achieved very good description of forward-central jet measurement*

- *Predictions for pPb are robust*

- *MC tool for calculations within HEF – LxJet has been upgraded to include Sudakov effects*

- *Open questions – description of the decorelations within CCFM. It includes Sudakov, and low x dynamics.*

- *Our results suggest that:*

  Sudakov effects are important at moderate values of $\Delta\phi$

  kt dependent gluon density with k.c and HEF framework works very well

  one does not need MPI to have good description of
  inside jet tag scenario witin tree level DGLAP provided one uses 2 → 3 ME