

DPS in pA collisions at LHC:how they can be observed?

B.Blok (Technion)

Based on

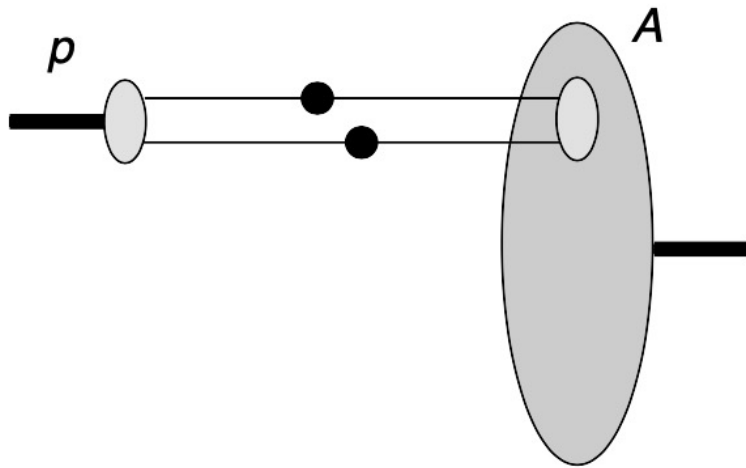
B.Blok,, F.A. Ceccopieri *Eur.Phys.J.C* 80 (2020) 3, 278;

Eur.Phys.J.C 80 (2020) 8, 762; *Phys.Rev.D* 101 (2020) 9, 0940;

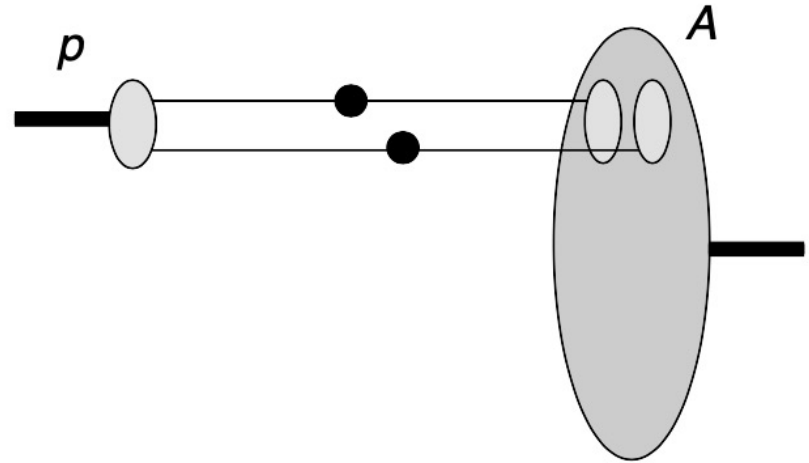
M.Alvioli,M.Azarkin.B. Blok,M.Strikman

Eur.Phys.J.C 79 (2019) 6, 482

MPI@LHC 2021 11-15 October 2021



a)



b)

DPS in pA where first studied in Strikman, Treleani 2002

Basic observation: there is DPS1-diagram a) like DPS in pp, but there is also diagram b) called DPS2 sometimes—two nucleons at the same impact parameter. The latter process is enhanced by factor $A^{1/3}$ realistic estimate shows for $A=200$ the ratio of pA and pp DPS cross sections is approximately 3.

QCD correctons were considered in Blok, Strikman, Wiedemann (2013)

$$R_{pA}^{4jet}(x_1, x_2, x'_1, x'_2) \equiv \frac{d\sigma_{4jet}^{pA}(x_1, x_2, x'_1, x'_2)}{d\hat{t}_1 d\hat{t}_2} \bigg/ \frac{A}{S} \frac{d\sigma_{2jet}(x'_1, x_1)}{d\hat{t}_1} \frac{d\sigma_{2jet}(x'_2, x_2)}{d\hat{t}_2}$$

$$= 1 + \frac{S}{A} \frac{A-1}{A} \int T^2(b) d^2b \frac{G_p(x'_1, x'_2)}{f_p(x'_1) f_p(x'_2)},$$

$$R_{pA}^{4jet}(x_1, x_2, x'_1, x'_2) = 1 + S W(A) K(x'_1, x'_2) \quad W(A) = \frac{A-1}{A^2} \int d^2b T^2(b)$$

$$S W(A) \sim 2.1 \quad S=15 \text{ mb}, A=200$$

$$K(x'_1, x'_2) = \frac{G_p(x'_1, x'_2, 0)}{f_p(x'_1) f_p(x'_2)} \quad \text{So the DPS in pA may measure longitudinal correlations of partons in the nucleon}$$

Question: how to see DPS2?

Need to subtract Leading twist contribution. Recently for the first time observed by LHCb in D system

Phys.Rev.Lett. 125 (2020) 21, 212001

*New method developed in
Alvioli, Azarkin, Blok, Strikman (2019)*

$$\sigma_{pA} = A \frac{\sigma_1 \sigma_2}{\sigma_{eff}} + \sigma_1 \sigma_2 \int d^2b T^2(b)$$

In the b-space

$$\frac{d\sigma_{pA}^{DPS}}{d^2b} = \sigma_{pN} T_A(b) + \sigma_1 \sigma_2 T^2(b).$$

Such different dependences on impact parameter in pA collisions can be used for unambiguous extraction of DPS2 from the data on pA scattering eliminating SPS and DPS1 backgrounds. So we can subtract SPS background (Leading twist)

Question: can one indeed use this method to extract DPS2, what is the statistics needed for extraction and are there enough DPS2 events in pA collisions in 4 jet and dijet+Z,W processes to be measured in current and future runs?

Answer: all these processes can be studied at ATLAS and CMS with already the available data.

Basic formalism: mean field, corrections to mean field in pA are much smaller than in pp (Blok, Strikman, Wiedemann, 2013).

$$\frac{d\sigma_{DPS}^{CD}}{d\Omega_1 d\Omega_2} = \frac{m}{2} \sum_{i,j,k,l} \sum_{N=p,n} \sigma_{\text{eff}}^{-1} f_p^i(x_1) f_p^j(x_2) f_N^k(x_3) f_N^l(x_4) \frac{d\hat{\sigma}_{ik}^C}{d\Omega_C} \frac{d\hat{\sigma}_{jl}^D}{d\Omega_D} \int d^2B T_N(B),$$

$$+ \frac{m}{2} \sum_{i,j,k,l} \sum_{N_3, N_4=p,n} f_p^i(x_1) f_p^j(x_2) f_{N_3}^k(x_3) f_{N_4}^l(x_4) \frac{d\hat{\sigma}_{ik}^C}{d\Omega_C} \frac{d\hat{\sigma}_{jl}^D}{d\Omega_D} \int d^2B T_{N_3}(B) T_{N_4}(B)$$

$$\rho^{(p,n)}(\mathbf{r}) = \frac{\rho_0^{(p,n)}}{1 + e^{(r-R_0^{(p,n)})/a_{(p,n)}}}, \quad T_{p,n}(B) = \int dz \rho^{(p,n)}(B, z),$$

$$\sigma_{eff}^{ATLAS} = 15 \pm 3 \text{ (stat.) } {}_{-3}^{+5} \text{ (syst.) mb,}$$

$$\sigma_{eff}^{CMS} = 20.7 \pm 0.8 \text{ (stat.) } \pm 6.6 \text{ (syst.) mb}$$

$$\bar{\sigma}_{eff} = 18 \pm 6 \text{ mb.}$$

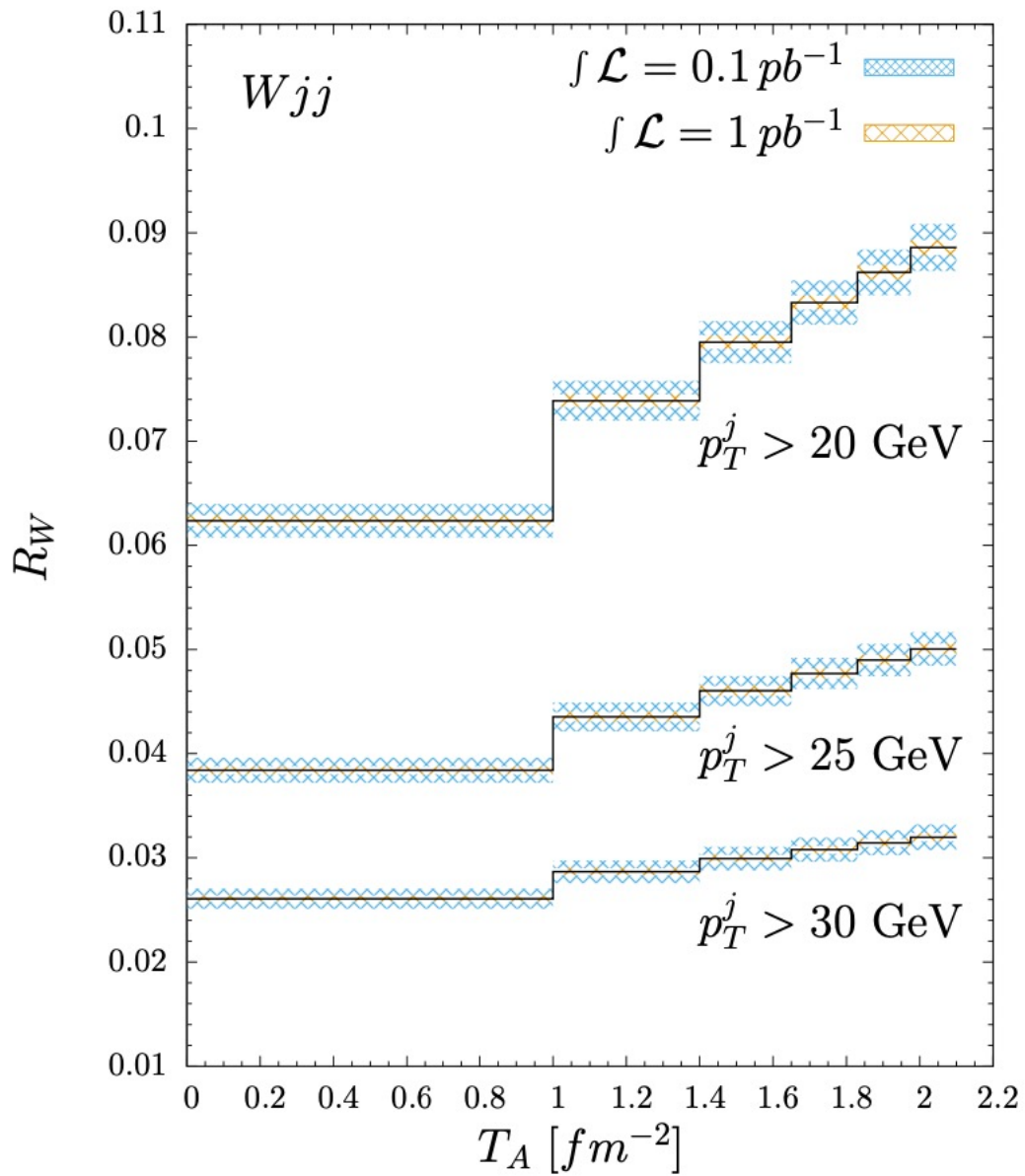
The nuclear pdfs include shadowing corrections

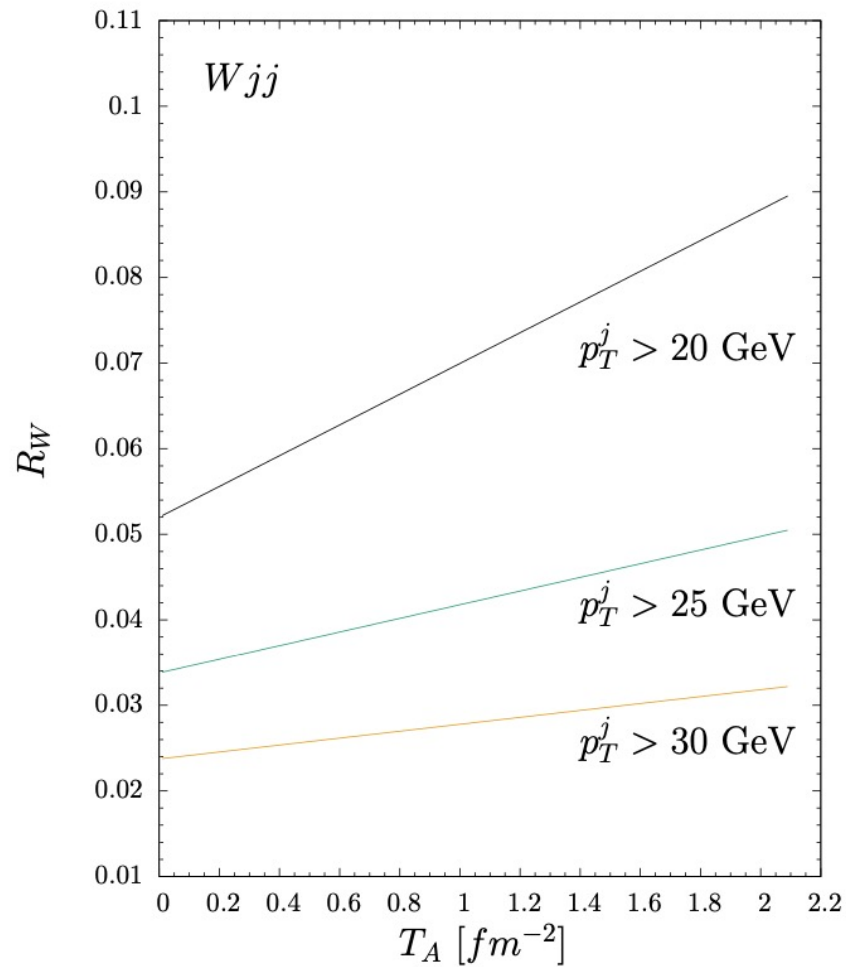
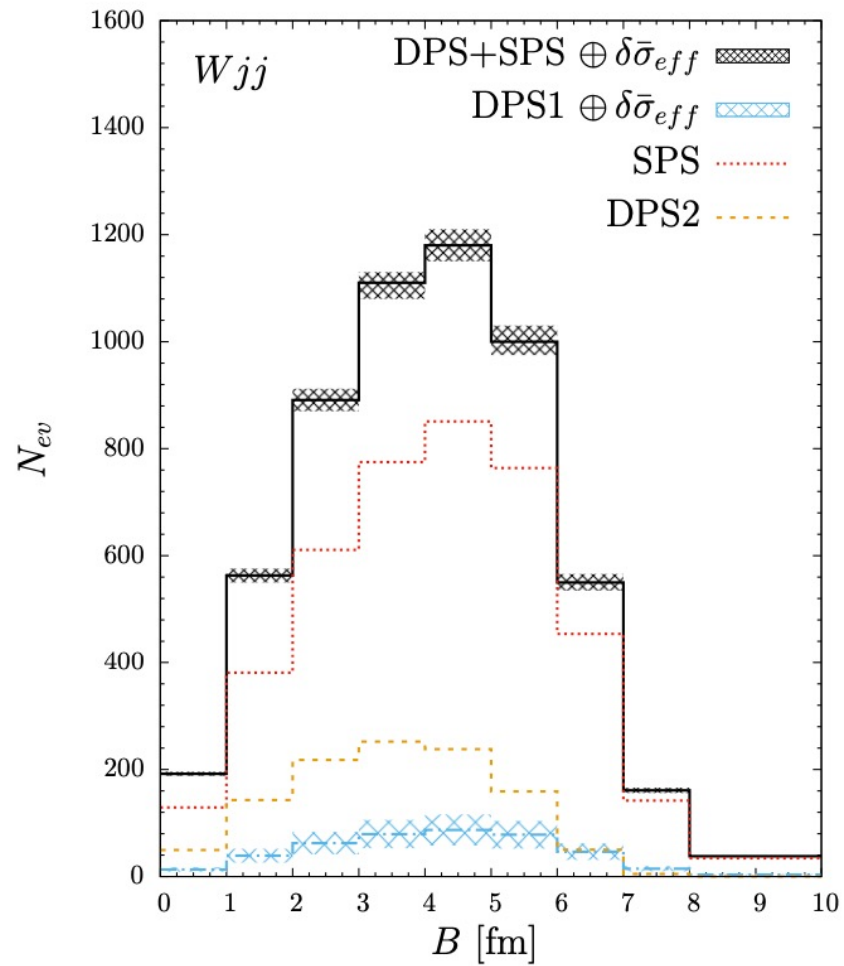
Example 1:Wjj process

$$R_W(T) = N_{Wjj}(T)/N_W(T).$$

Basic idea: to eliminate inaccuracies we take the ratio of the number of Wjj events and the number of W events, proportional to T(B).

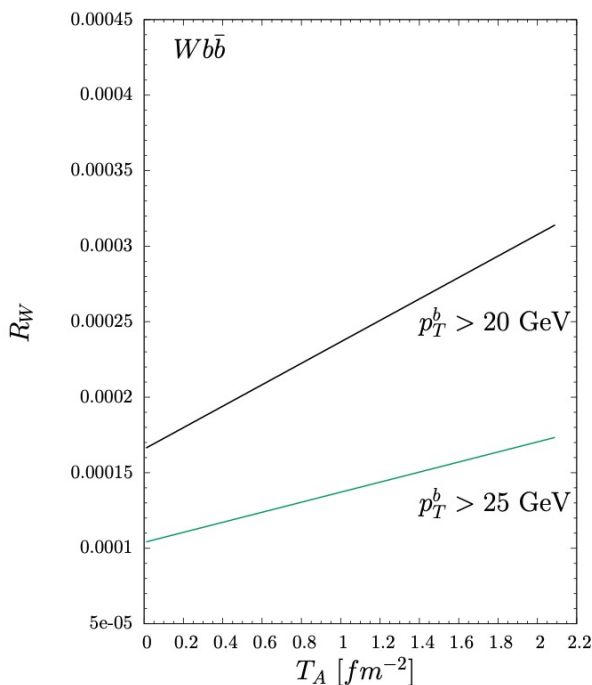
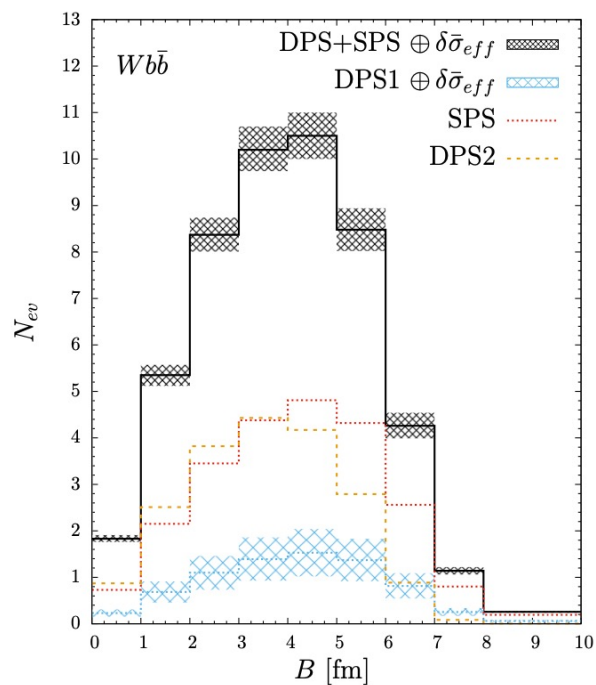
	$p_T^j > 20 \text{ GeV}$	$p_T^j > 25 \text{ GeV}$	$p_T^j > 30 \text{ GeV}$
σ^{Wjj}	[nb]	[nb]	[nb]
DPS1	19 ± 6	8 ± 3	4 ± 2
DPS2	49	22	11
SPS	81	57	41
Tot	149 ± 6	87 ± 3	56 ± 2

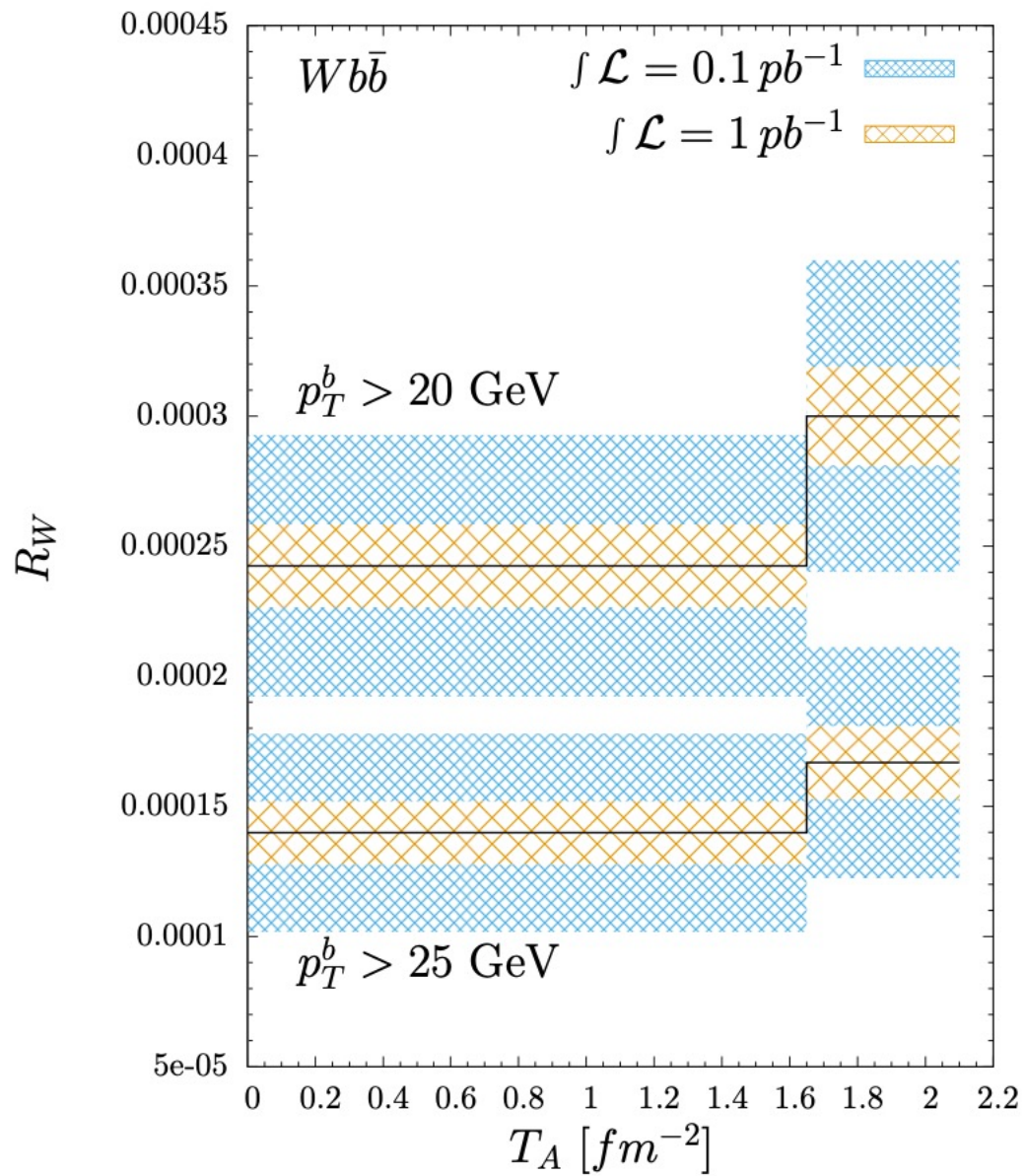




Similar results for W^+ two b -jets.

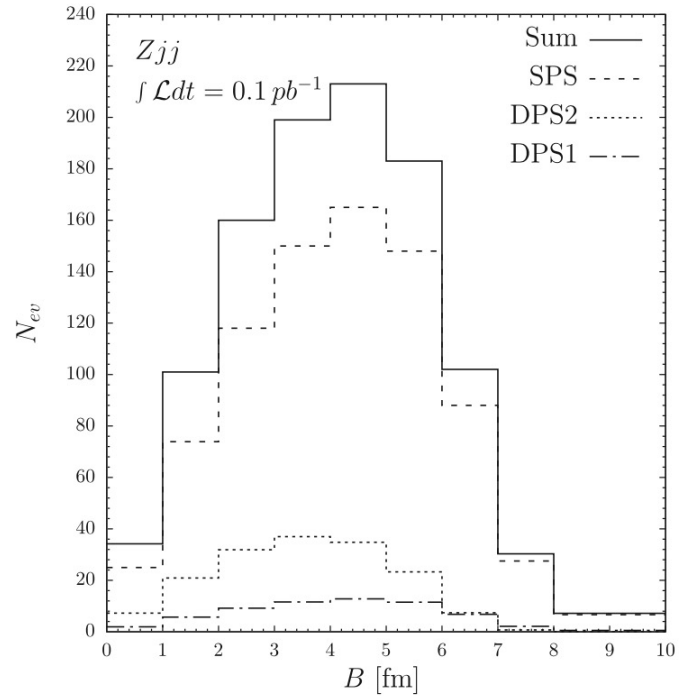
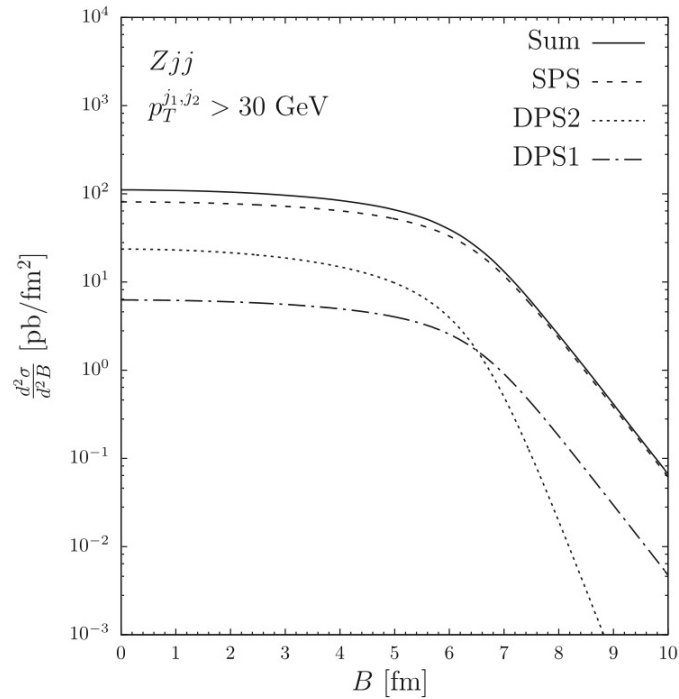
	$p_T^b > 20$ GeV	$p_T^b > 25$ GeV	$p_T^b > 30$ GeV
$\sigma^{Wb\bar{b}}$	[pb]	[pb]	[pb]
DPS1	74 ± 25	35 ± 12	18 ± 6
DPS2	196	92	48
SPS	234	158	114
Tot	504 ± 25	285 ± 12	180 ± 6

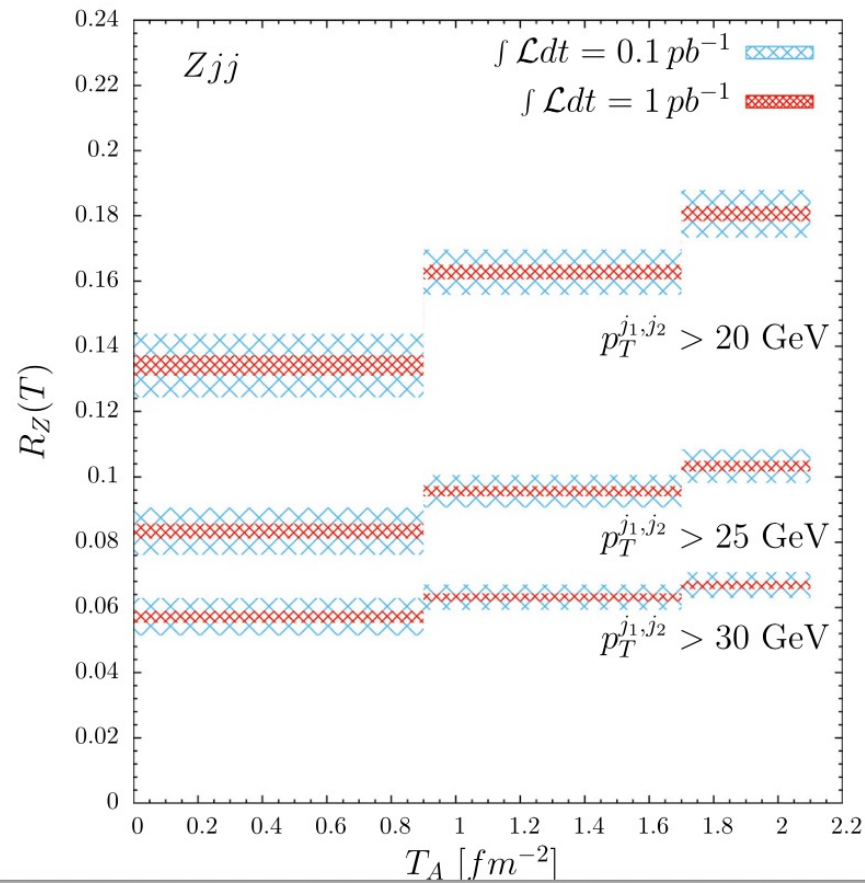
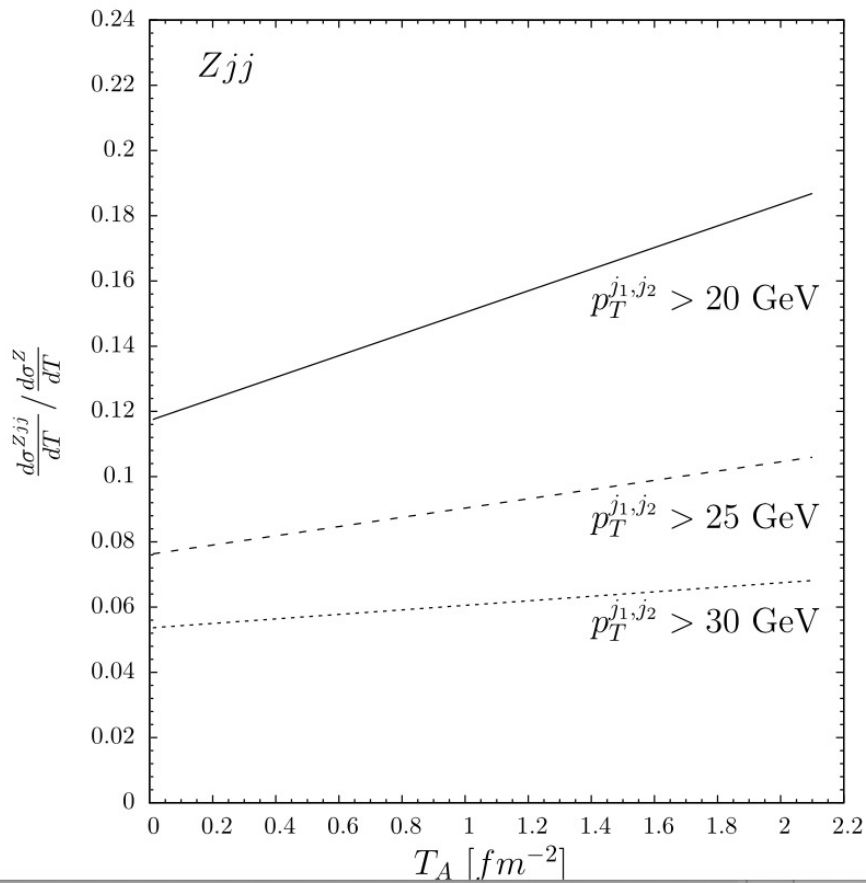




Z+dijet

Zjj	DPS1 (pb)	DPS2 (pb)	SPS (pb)	Sum (pb)	$\sigma(Zjj)/\sigma(Z)$	f_{DPS1}	f_{DPS2}
$p_T^{j_1, j_2} > 20, 20 \text{ GeV}$	2971	7814	15,940	26,725	0.166	0.111	0.292
$p_T^{j_1, j_2} > 25, 25 \text{ GeV}$	1270	3341	11,024	15,636	0.097	0.081	0.213
$p_T^{j_1, j_2} > 30, 30 \text{ GeV}$	621	1632	8030	10,283	0.064	0.060	0.158





Two dijets

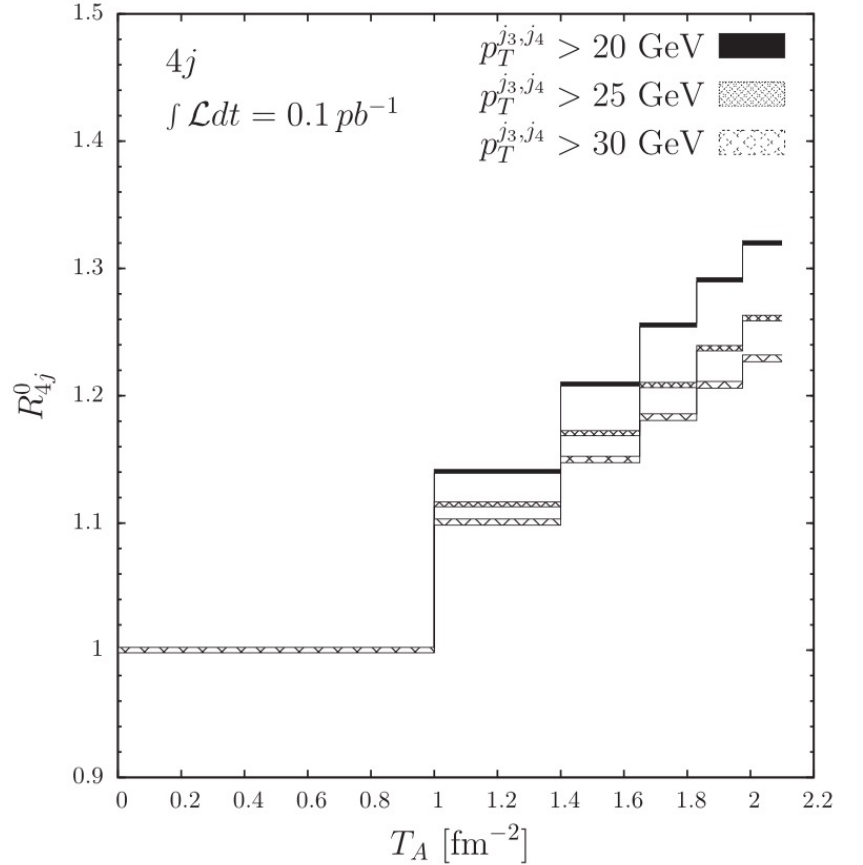
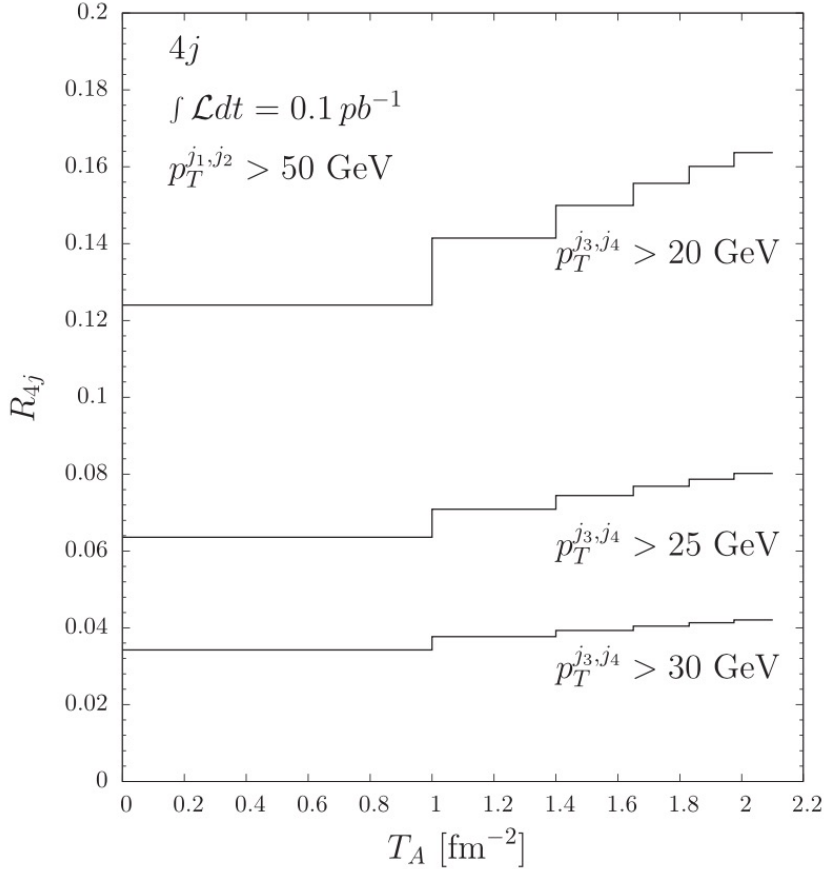
$$N_{ev}(T_i, T_{i+1}) = \int d^2B \frac{d^2\sigma_{pA}}{d^2B} \Theta(T_A(P) - T_A) \\ \times \Theta(T_{i+1} - T_A(B)), \quad R_{4j}^0(T_i, T_{i+1}) = \frac{N_{4j}(T_i, T_{i+1})}{N_{2j}(T_i, T_{i+1})} \left(\frac{N_{4j}(T_0, T_1)}{N_{2j}(T_0, T_1)} \right)^{-1};$$

$$R_{4j}(T_i, T_{i+1}) = N_{4j}(T_i, T_{i+1}) / N_{2j}(T_i, T_{i+1})$$

*The double ratio to decrease sensitivity
to higher order corrections*

TABLE II. Predictions for $4j$ DPS and SPS cross sections in pA collisions in fiducial phase space, for different cuts on jets transverse momenta.

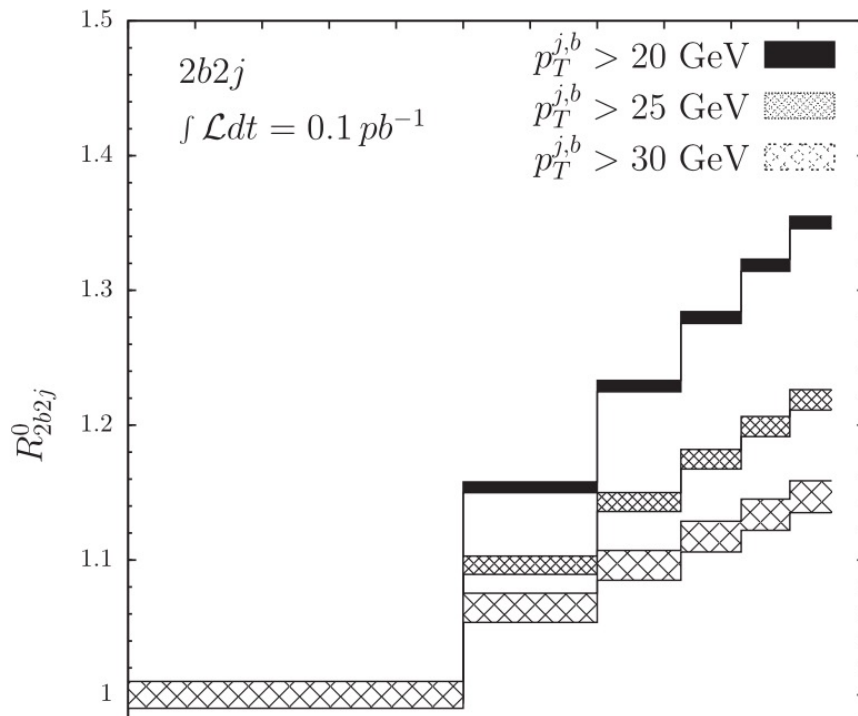
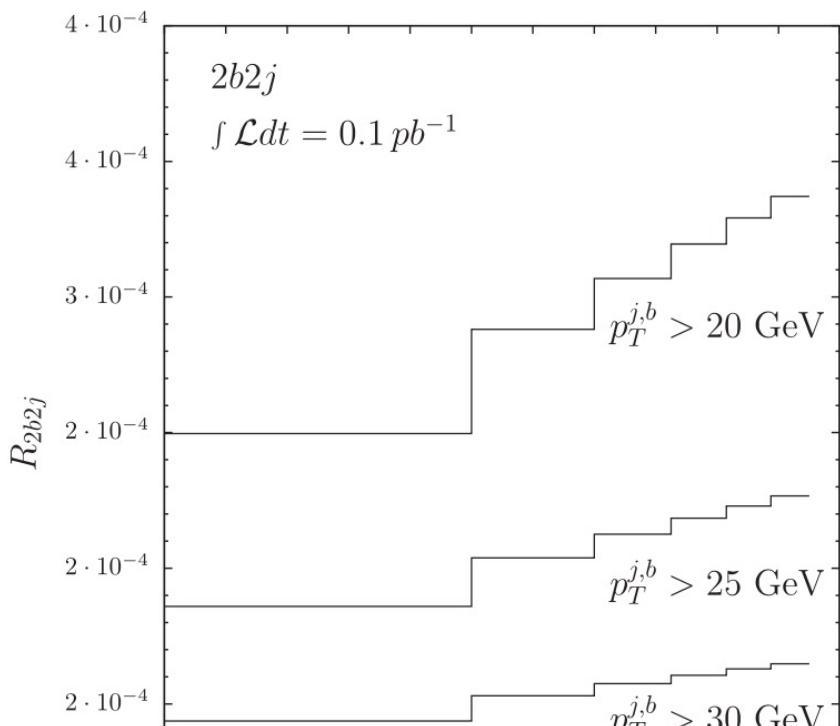
	DPS1	DPS2	SPS	Sum	$\sigma(4j)/\sigma(2j)$	f_{DPS1}	f_{DPS2}
$4j$	(μb)	(μb)	(μb)	(μb)			
$p_T^{j_3, j_4} > 20 \text{ GeV}$	26.0	72.2	170.9	269.2	0.15	0.13	0.27
$p_T^{j_3, j_4} > 25 \text{ GeV}$	10.8	30.2	92.9	133.9	0.07	0.10	0.22
$p_T^{j_3, j_4} > 30 \text{ GeV}$	5.1	14.3	51.4	70.9	0.04	0.09	0.20



2j2b

TABLE III. Predictions for $2b2j$ DPS and SPS cross sections in pA collisions in fiducial phase space for different cuts on jets transverse momenta.

	DPS1	DPS2	SPS	Sum	$\sigma(2b2j)/\sigma(2j)$	f_{DPS1}	f_{DPS2}
$2b2j$	(μb)	(μb)	(μb)	(μb)	$\times 10^{-4}$		
$p_T^{b,j} > 20 \text{ GeV}$	2.2	6.2	13.0	21.4	3.0	0.15	0.29
$p_T^{b,j} > 25 \text{ GeV}$	0.4	1.2	4.7	6.4	2.1	0.09	0.19
$p_T^{b,j} > 30 \text{ GeV}$	0.1	0.3	1.9	2.3	1.6	0.06	0.13



Conclusions

- There is enough statistics to see DPS2 in pA already with available data
- Additional work in particular calculation of NLO and NNLO corrections must be done to extract the longitudinal correlations due to large K factors in some channels.