NICA-SPD PROJECT

IWHSS-2022

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on behalf of the SPD collaboration

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31.8.2022

SPD AT NICA

NICA - Nuclotron-based Ion Collider fAcility

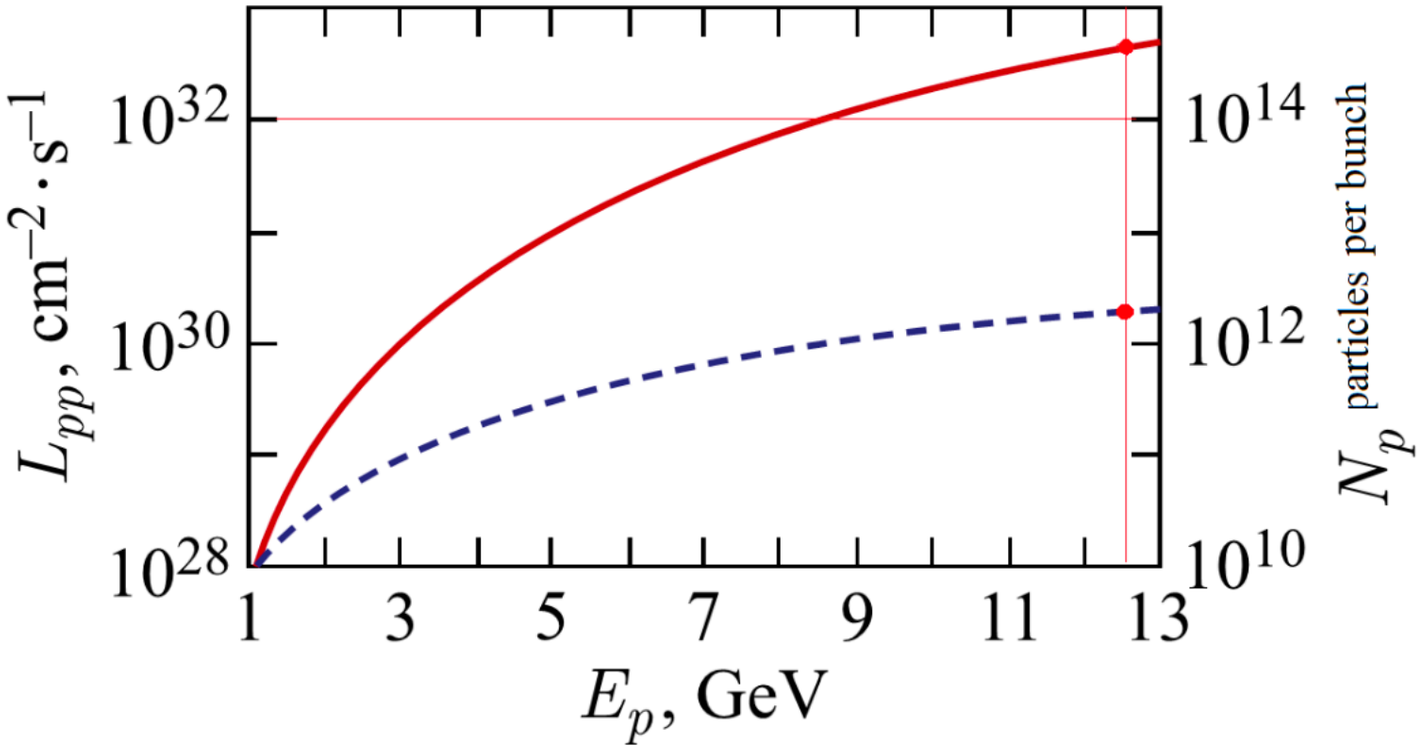
$p^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 27\ GeV$

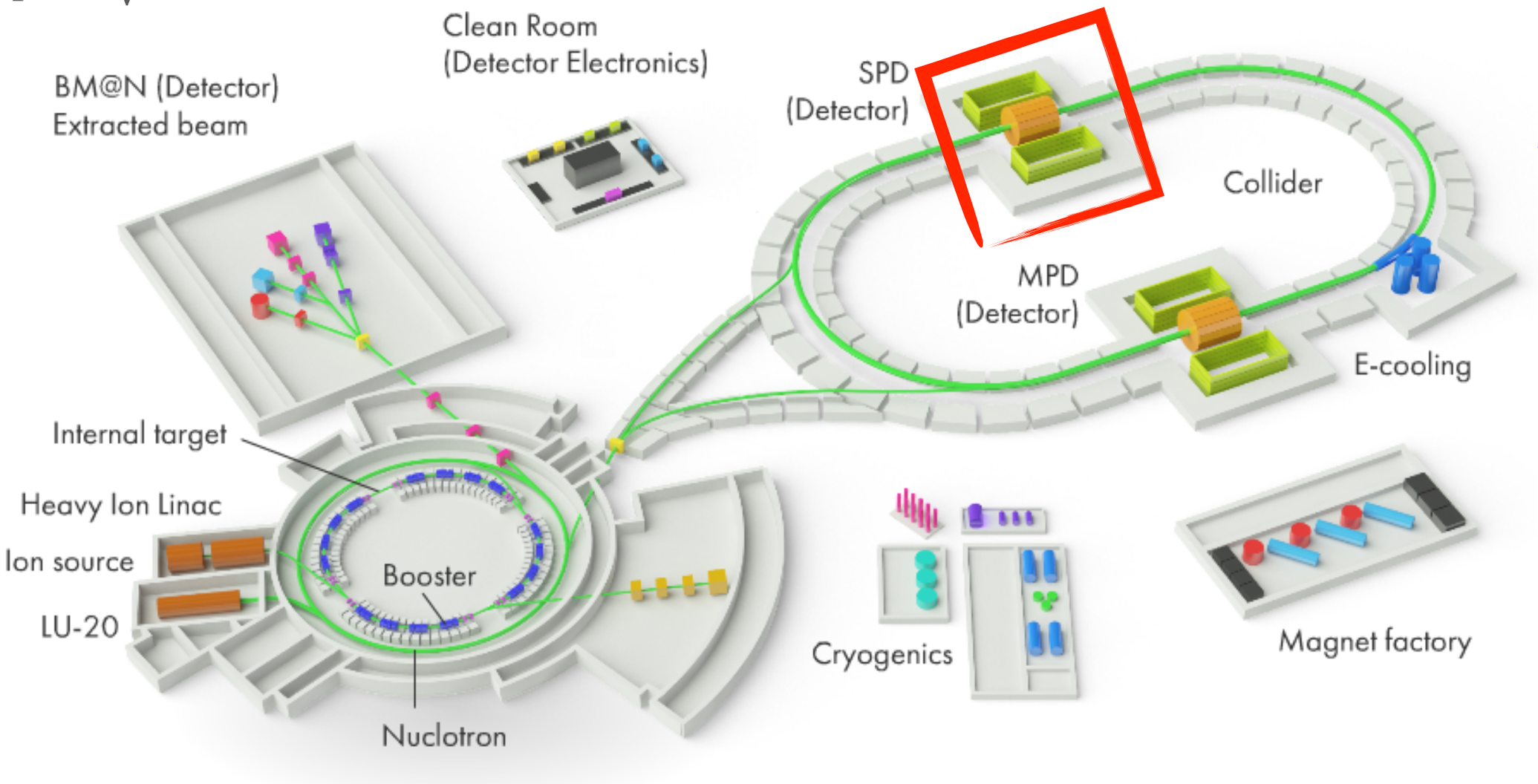
$d^{\uparrow}d^{\uparrow} : \sqrt{s} \leq 13.5\ GeV$

$d^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 19\ GeV$

U, L, T

|P|>70%



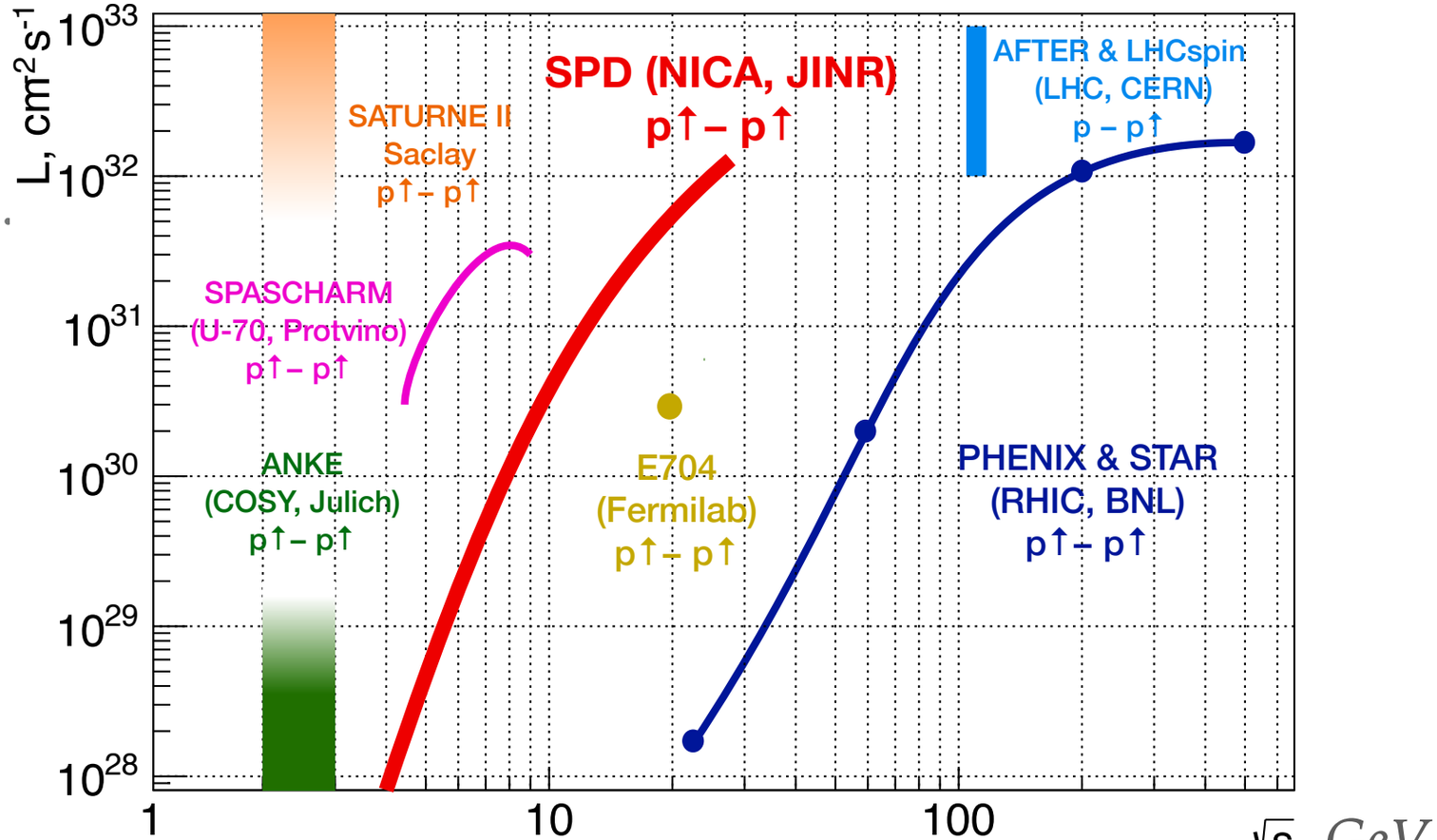


503 m

NICA

SPD & OTHERS

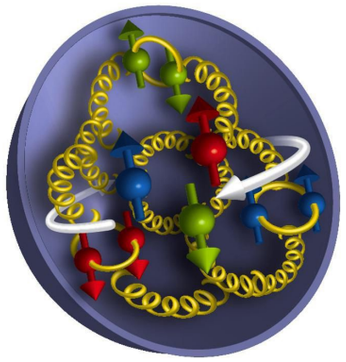
In the $p^{\uparrow}p^{\uparrow}$ mode:



Experimental facility	SPD @NICA	RHIC	EIC	AFTER @LHC	LHCspin
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^{\uparrow}$-$p^{\uparrow}$ $d^{\uparrow}$-$d^{\uparrow}$ $p^{\uparrow}$-d, p-$d^{\uparrow}$	$p^{\uparrow}$-$p^{\uparrow}$	$e^{\uparrow}$-$p^{\uparrow}$, $d^{\uparrow}$, ^{3}He$^{\uparrow}$	p-$p^{\uparrow}$, $d^{\uparrow}$	p-$p^{\uparrow}$
Center-of-mass energy $\sqrt{s_{NN}}$, GeV	≤27 (p-p) ≤13.5 (d-d) ≤19 (p-d)	63, 200, 500	20-140 (ep)	115	115
Max. luminosity, 10^{32} cm^{-2} s^{-1}	~1 (p-p) ~0.1 (d-d)	2	1000	up to ~10 (p-p)	4.7
Physics run	>2025	running	>2030	>2025	>2025

In the $d^{\uparrow}d^{\uparrow}$ mode at such energy NICA is unique

CONCEPT OF THE SPD PHYSICS PROGRAM



SPD - a universal facility for comprehensive study of polarized gluon content in proton and deuteron at large x

- Charmonia
- Open charm
- Prompt photons

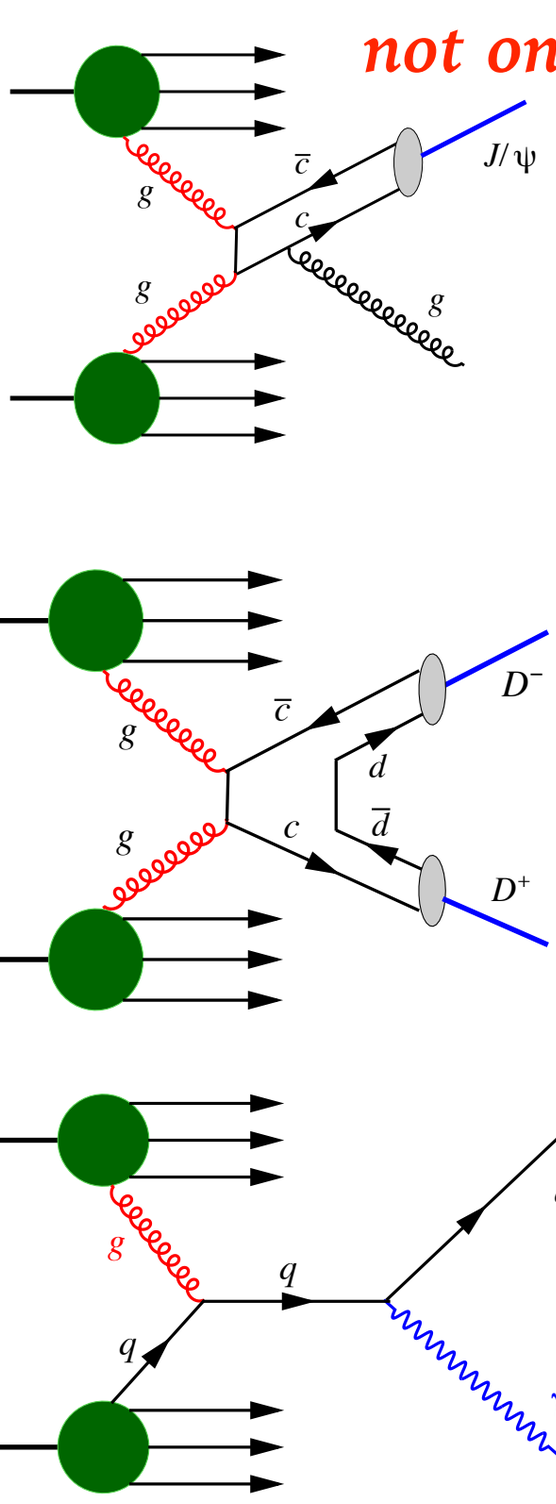
Other spin-related phenomena

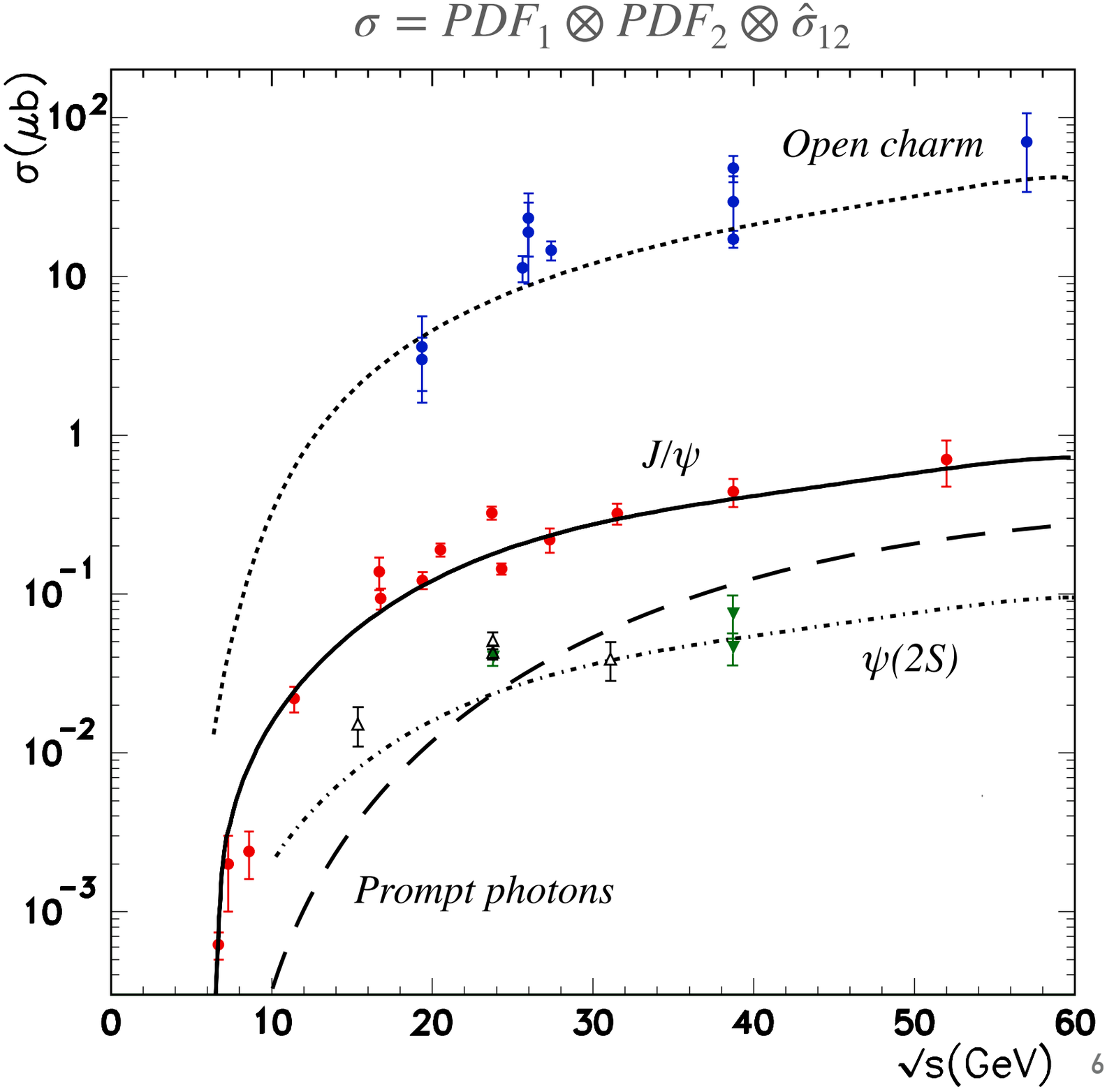
Other physics

Prog.Part.Nucl.Phys. 119 (2021) 103858
arXiv:2011.15005

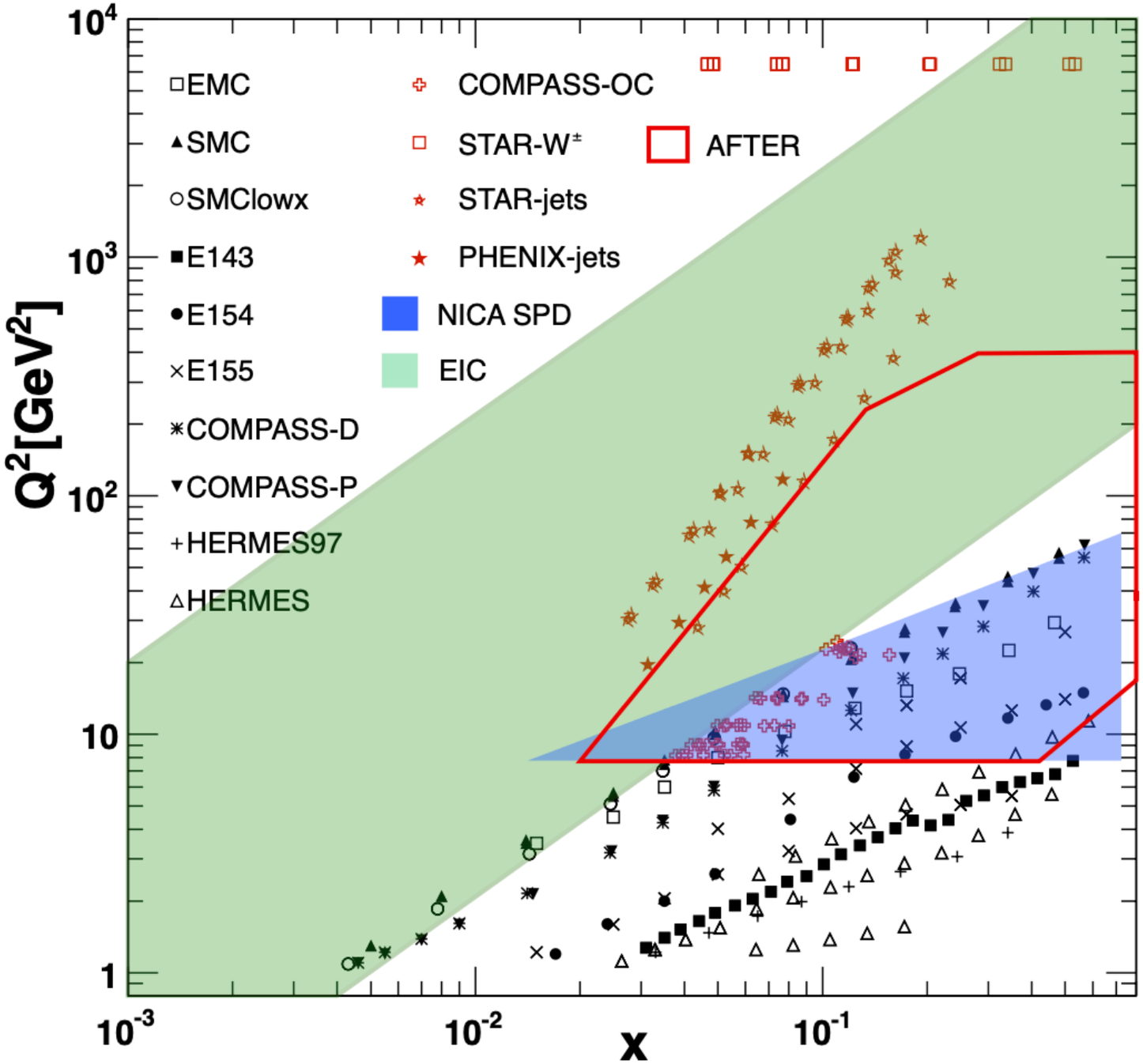
Phys.Part.Nucl. 52 (2021) 6, 1044
arXiv:2102.08477

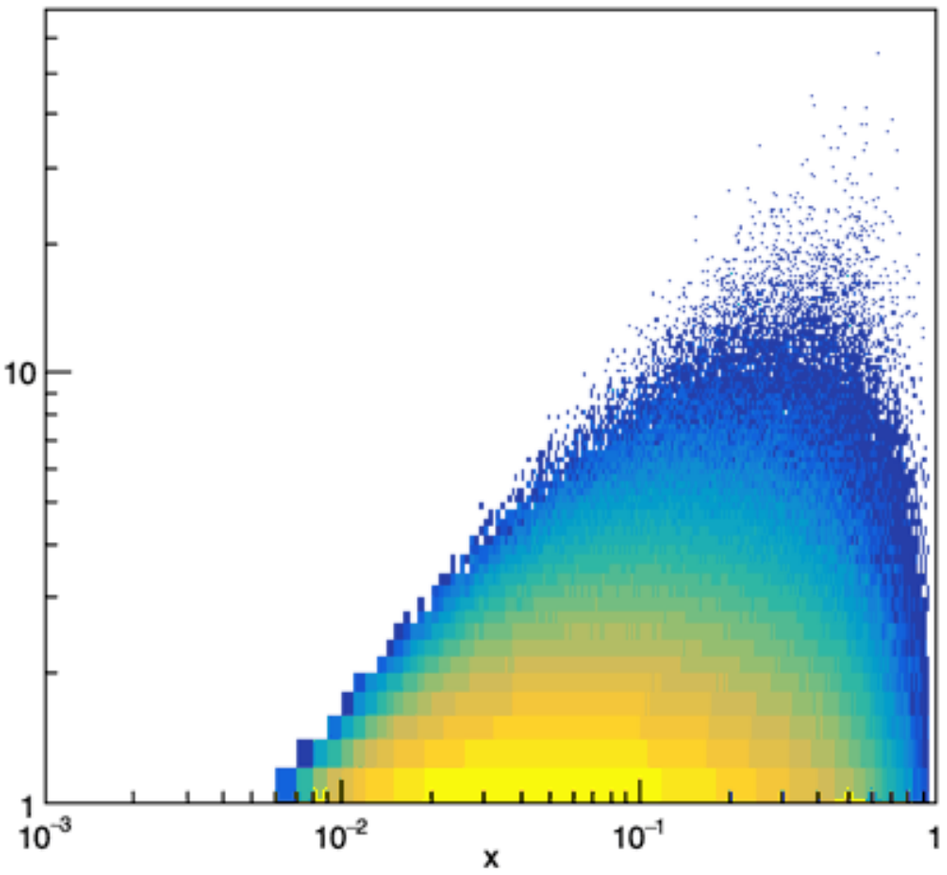
GLUON PROBES AT SPD





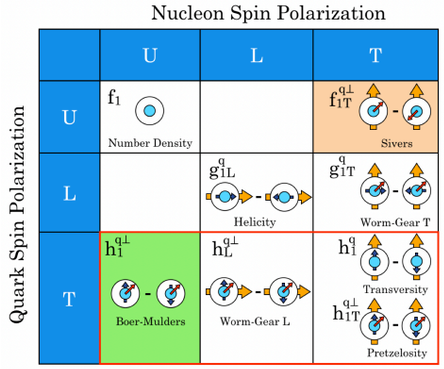
KINEMATIC RANGE





$Q^2 = 1\ GeV^2/c^2, < x > = 0.16$

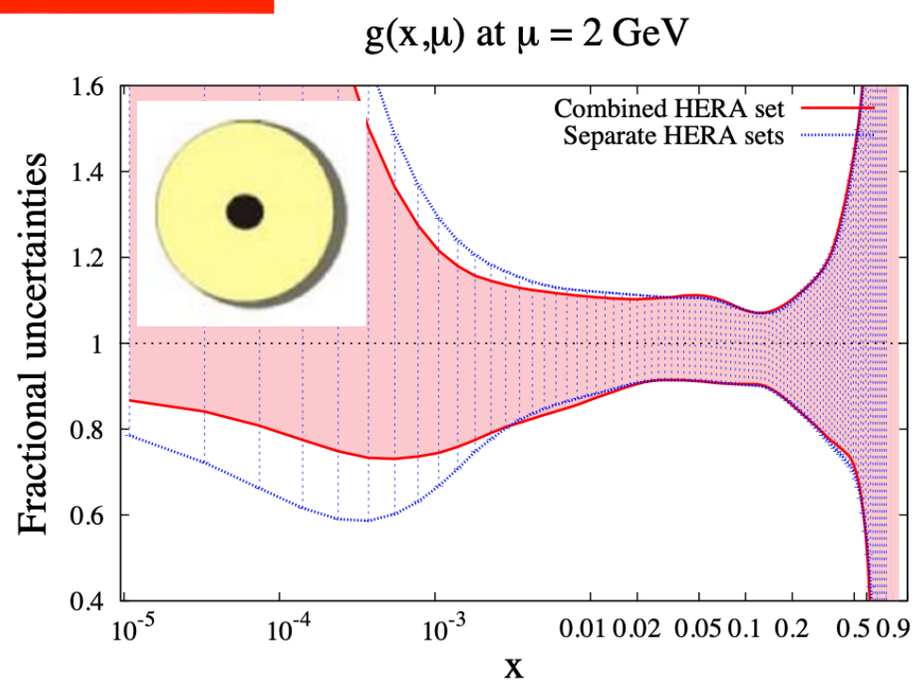
$Q^2 = 10\ GeV^2/c^2, < x > = 0.3$



PARTONIC STRUCTURE OF PROTON

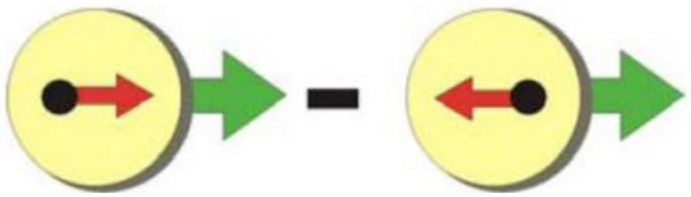
$\sigma(x_F,p_T)$ $A_{LL}(x_F,p_T)$ $A_{TT}(x_F,p_T)$ $A_N(x_F,p_T)$

Unpolarized gluons in proton at high x:



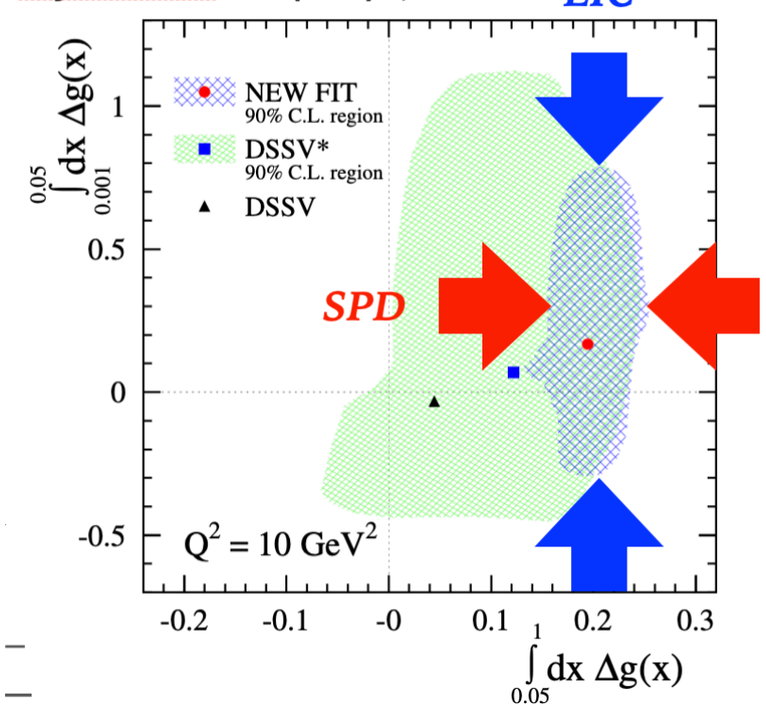
Spin crisis:

Gluon helicity

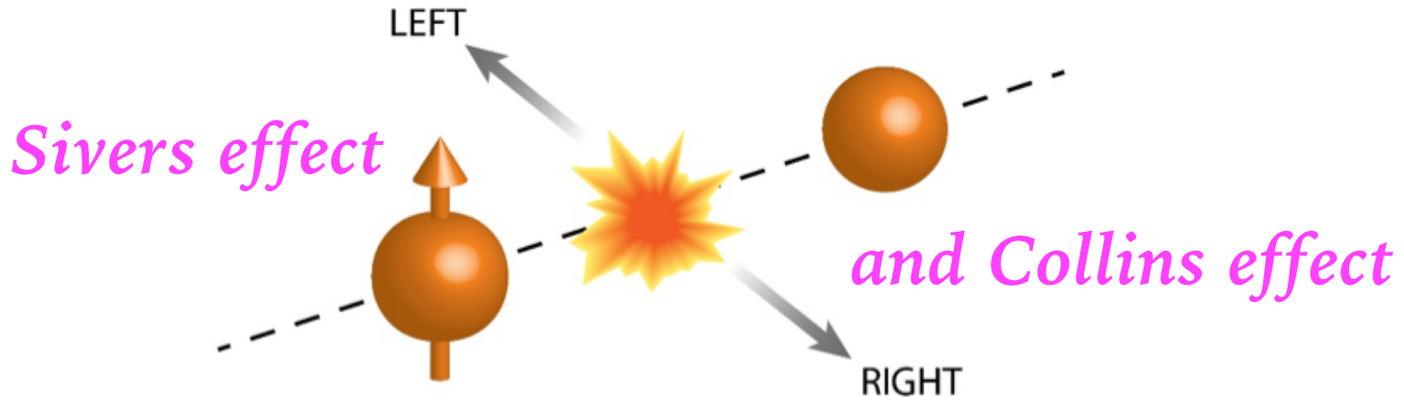


Phys.Rev.Lett. 113 (2014) 1, 012001

EIC

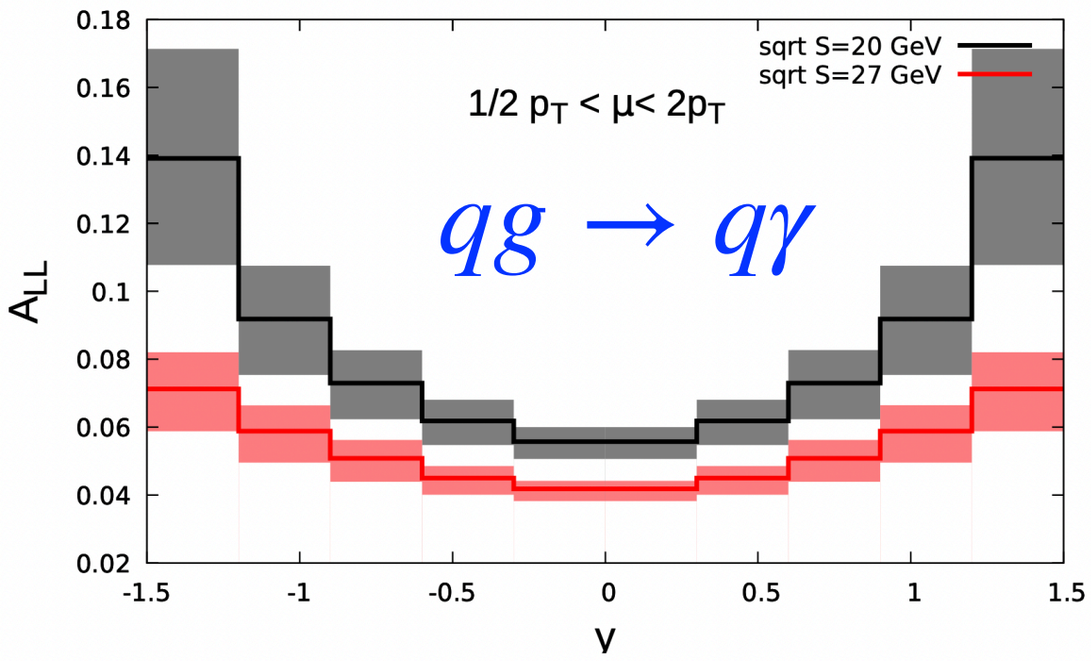


Gluon and quark TMD PDFs:

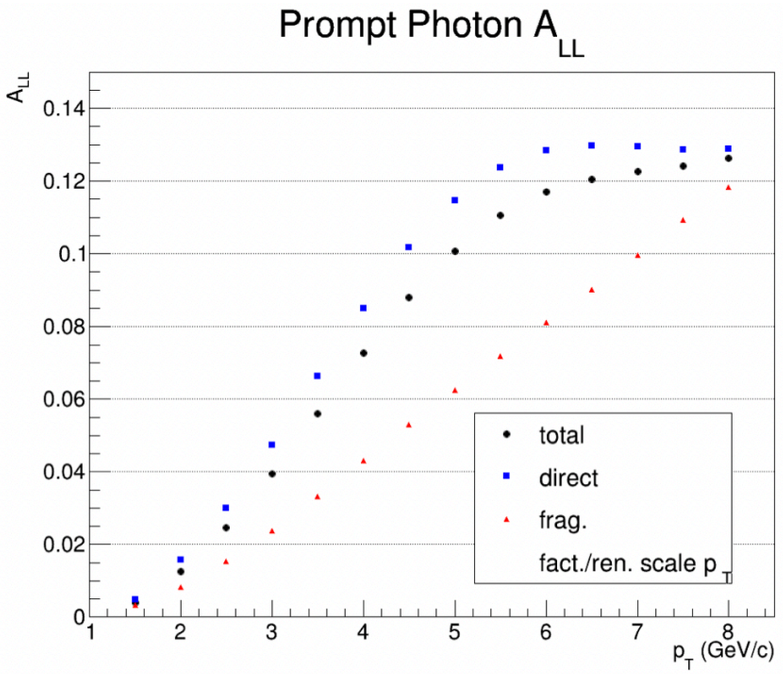


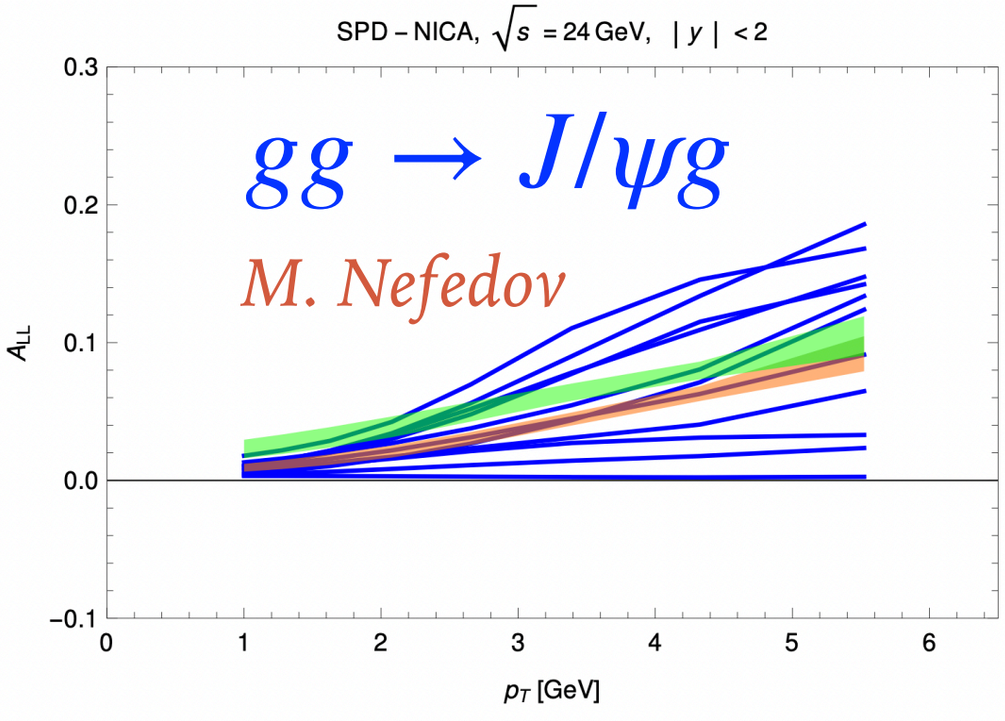
GLUON HELICITY FUNCTION Δg(x) : EXPECTATIONS FOR A_{LL}

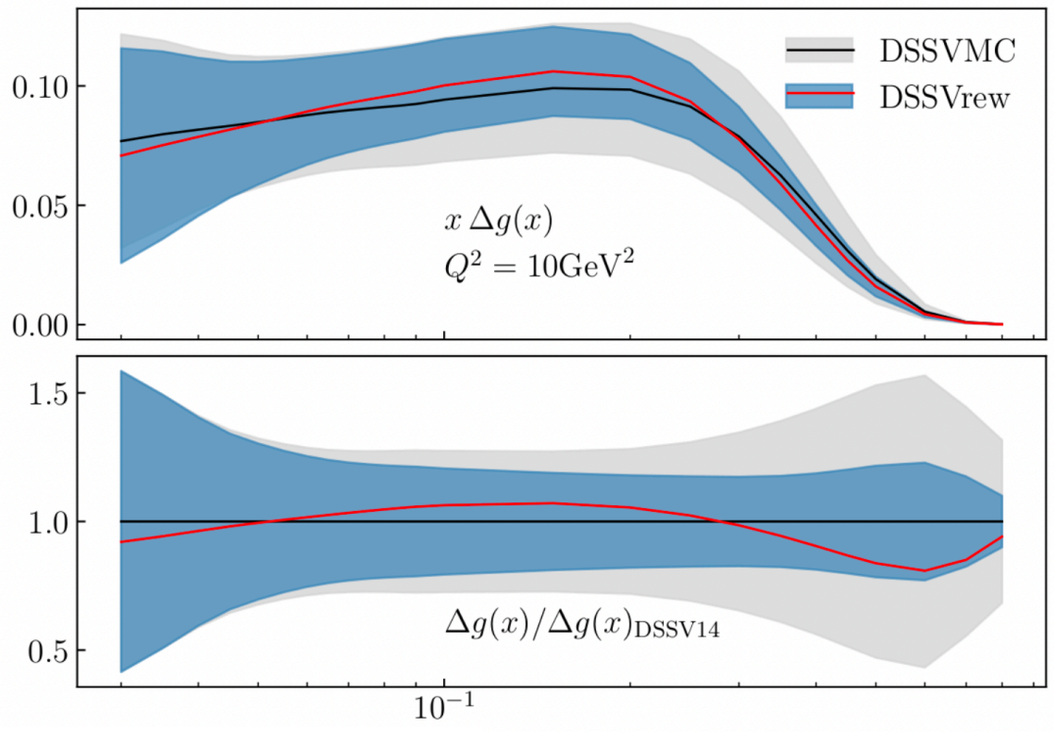
A. Shipilova



W. Vogelsang



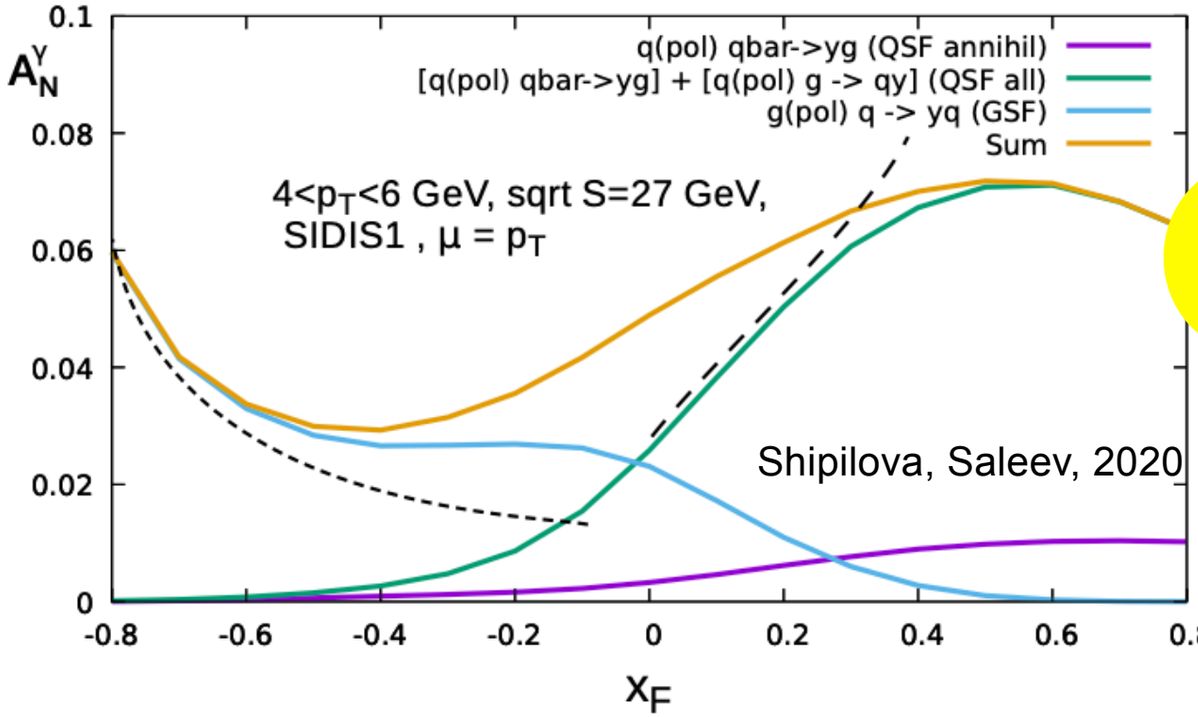


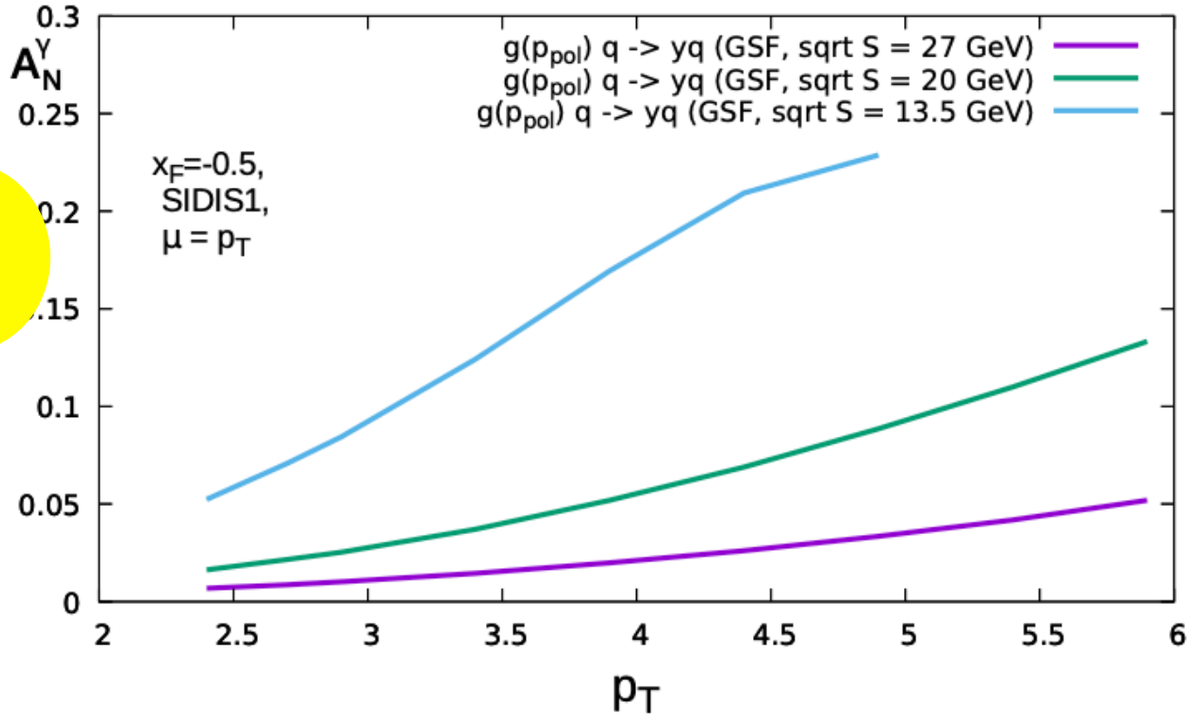


Vogelsang, Sassot, Borsa

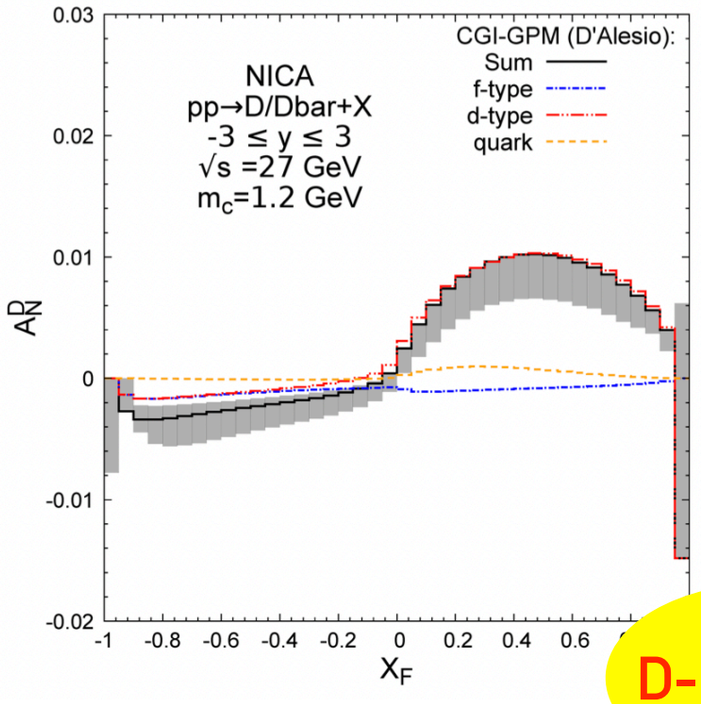
GLUON-INDUCED TMD EFFECTS: EXPECTATIONS FOR A_N

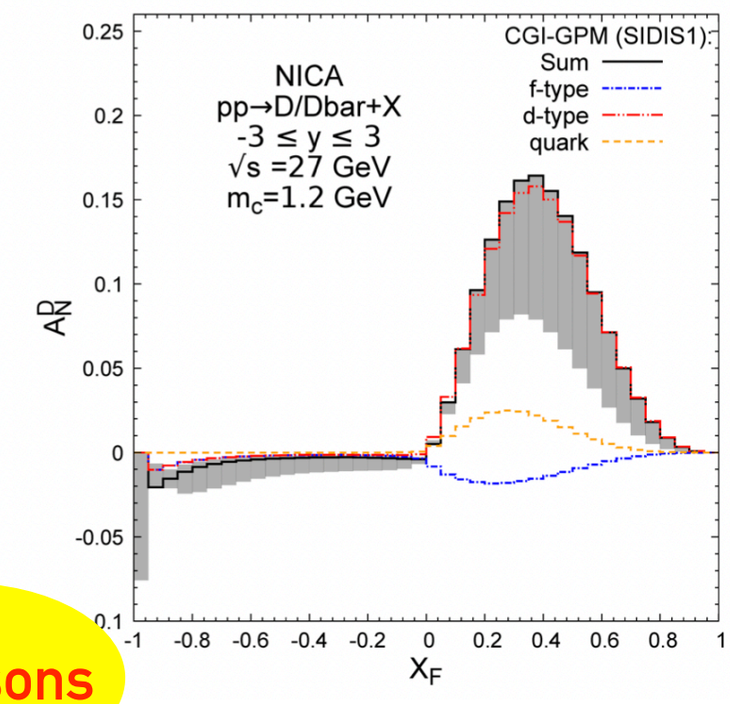
Sivers effect contribution



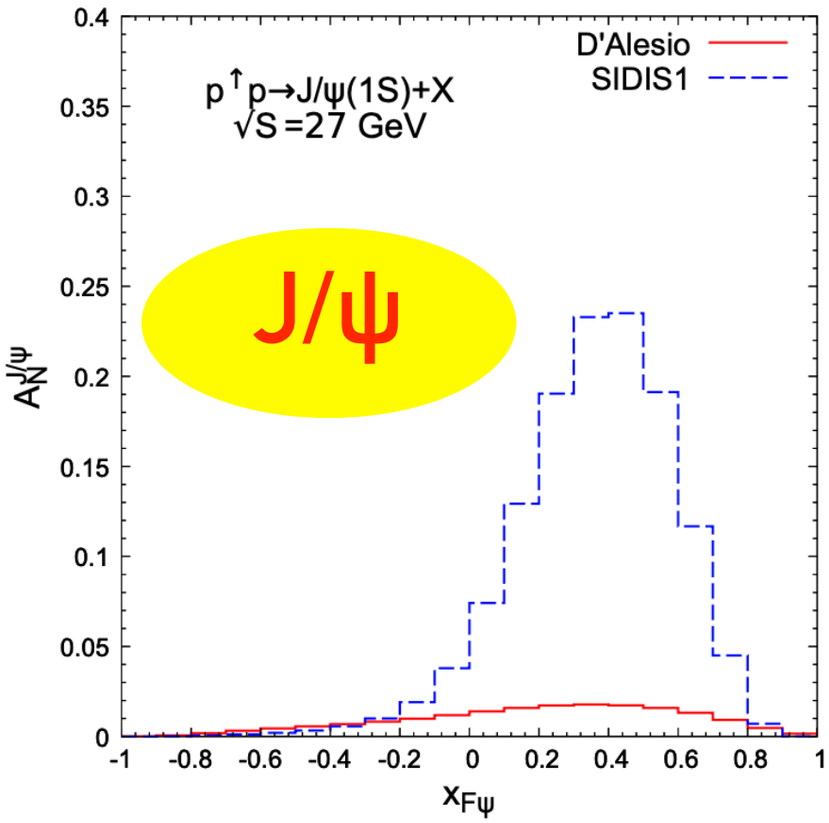


Saleev 2020



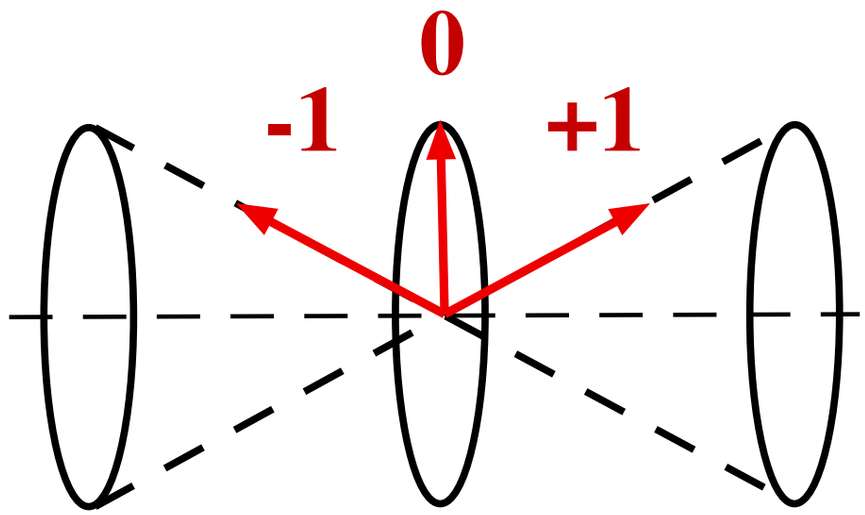


D-mesons



. . . AND DEUTERON

$\sigma(x_F,p_T)$, vector and tensor angular asymmetries



Nonbaryonic content of deuteron:

$$|6q\rangle = c_1|NN\rangle + c_2|\Delta\Delta\rangle + c_3|CC\rangle$$

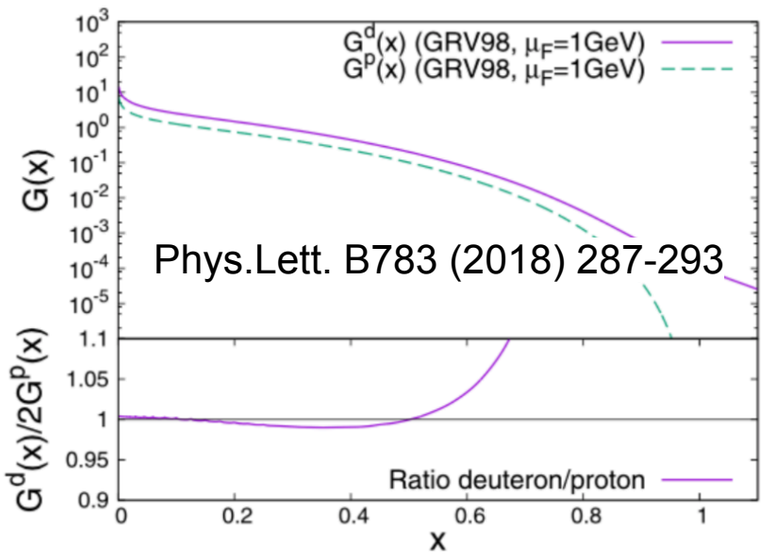
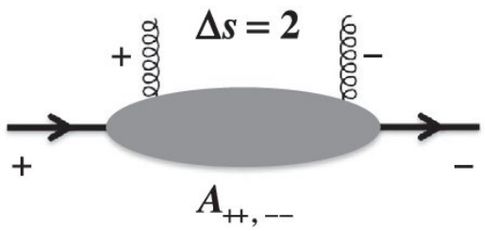
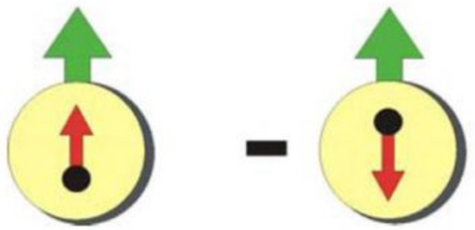


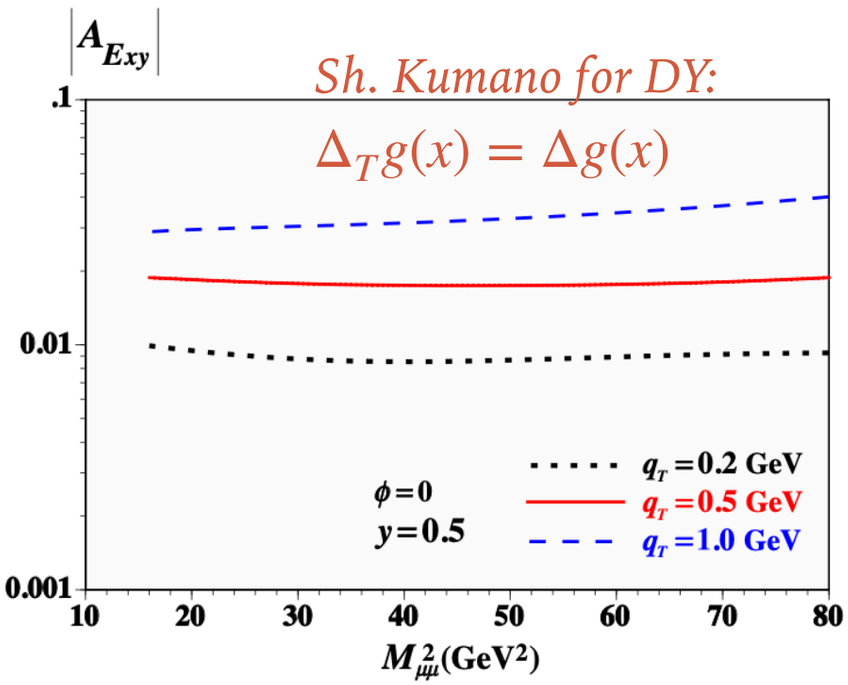
Fig. 6. Gluon PDF in the deuteron and in the nucleon.

Unpolarized gluons at high x:

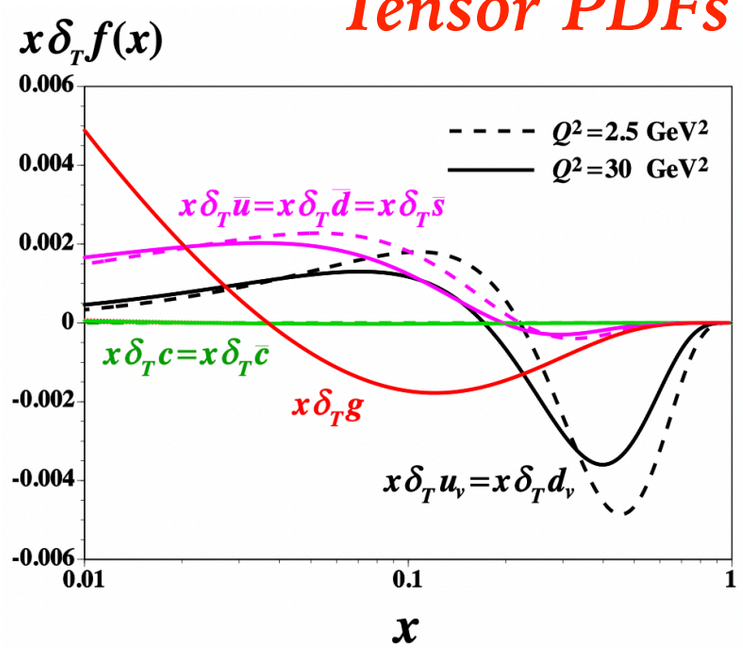
Gluon transversity



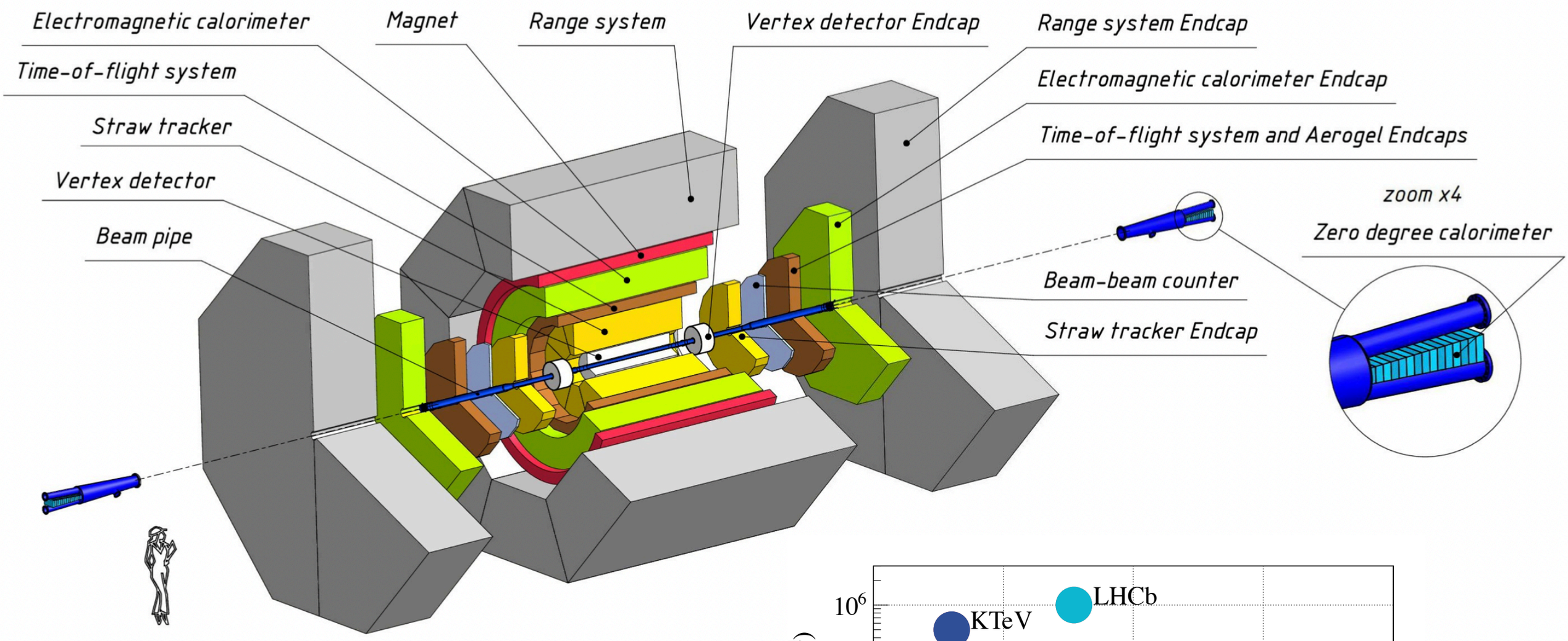




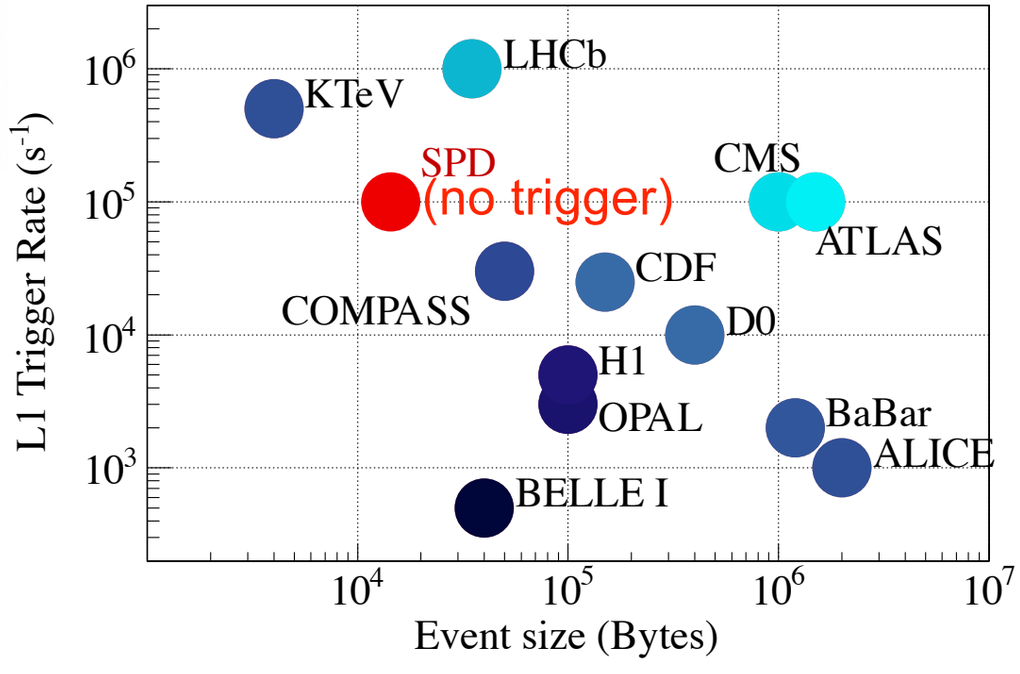
Tensor PDFs



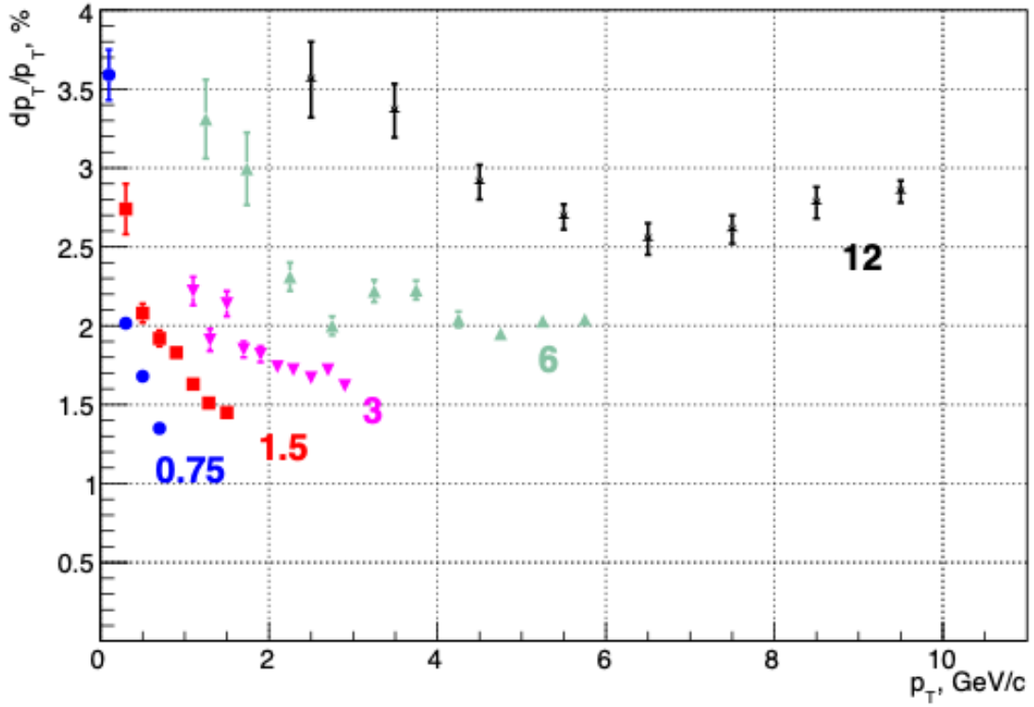
SPD DETECTOR

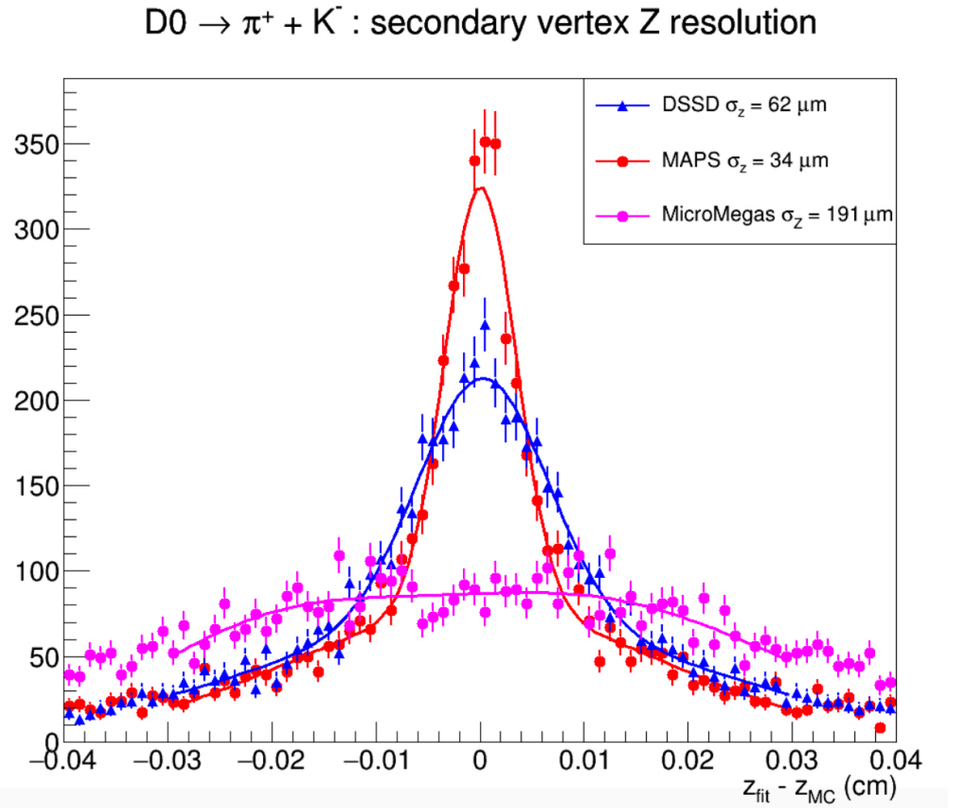


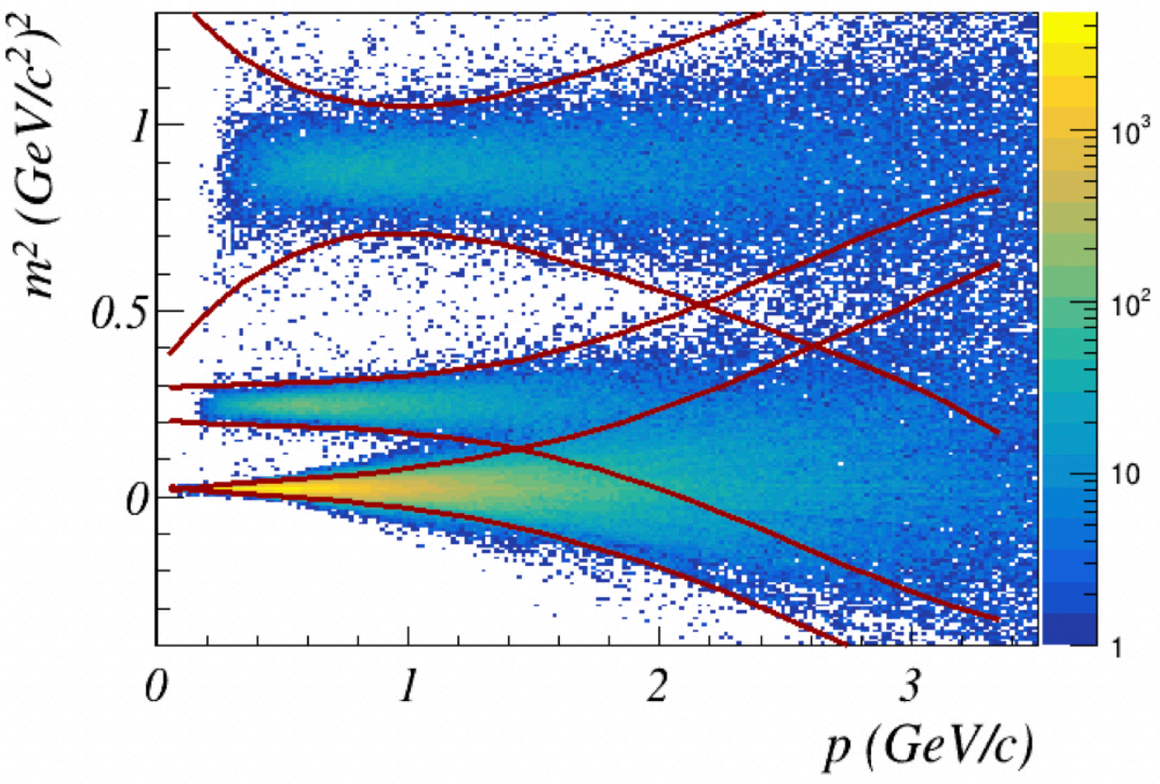
No hardware triggers to avoid possible bias!

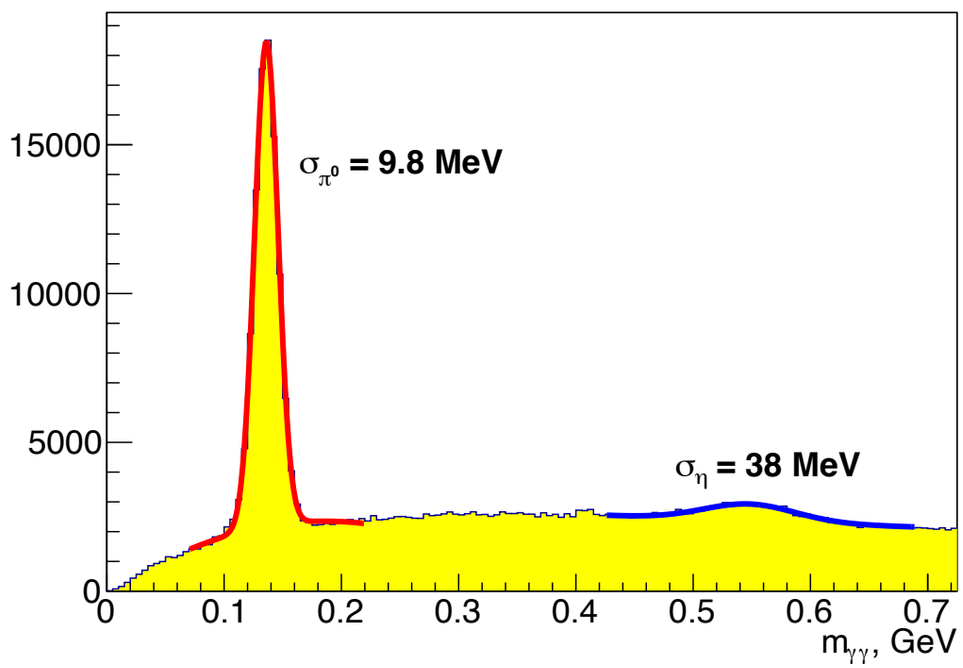


DETECTOR PERFORMANCE

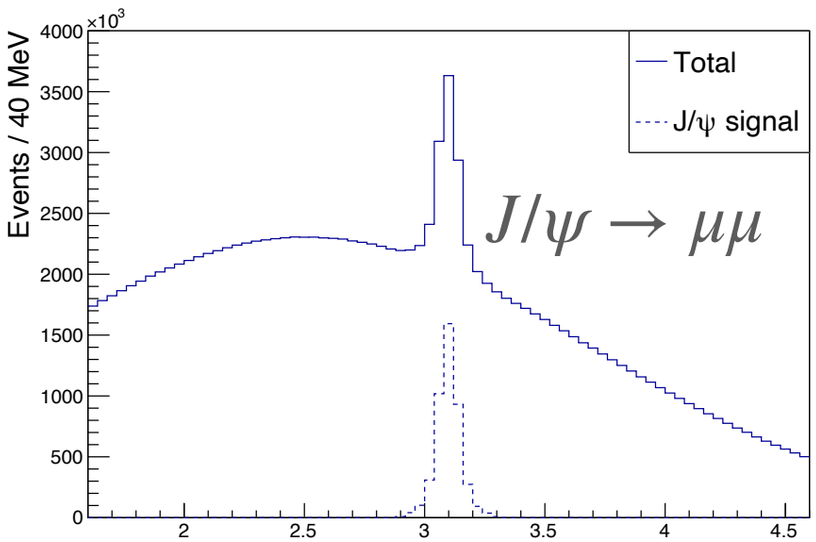


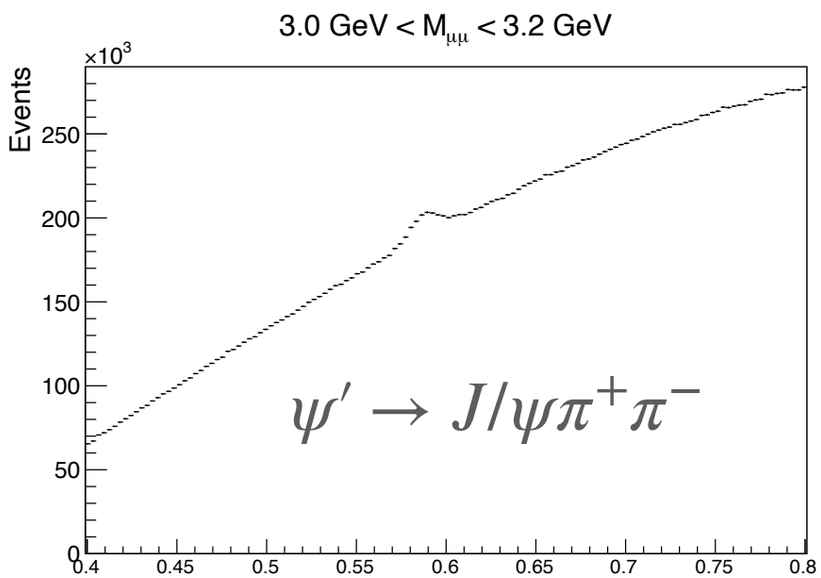


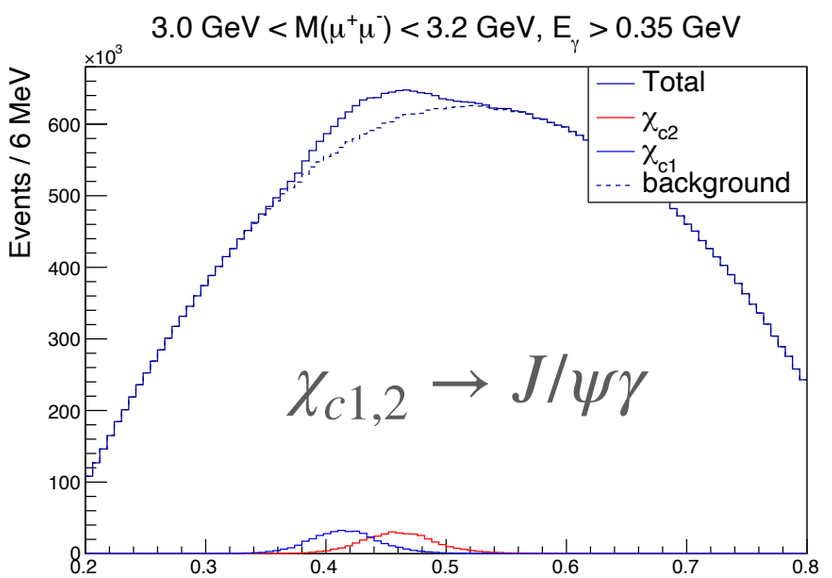


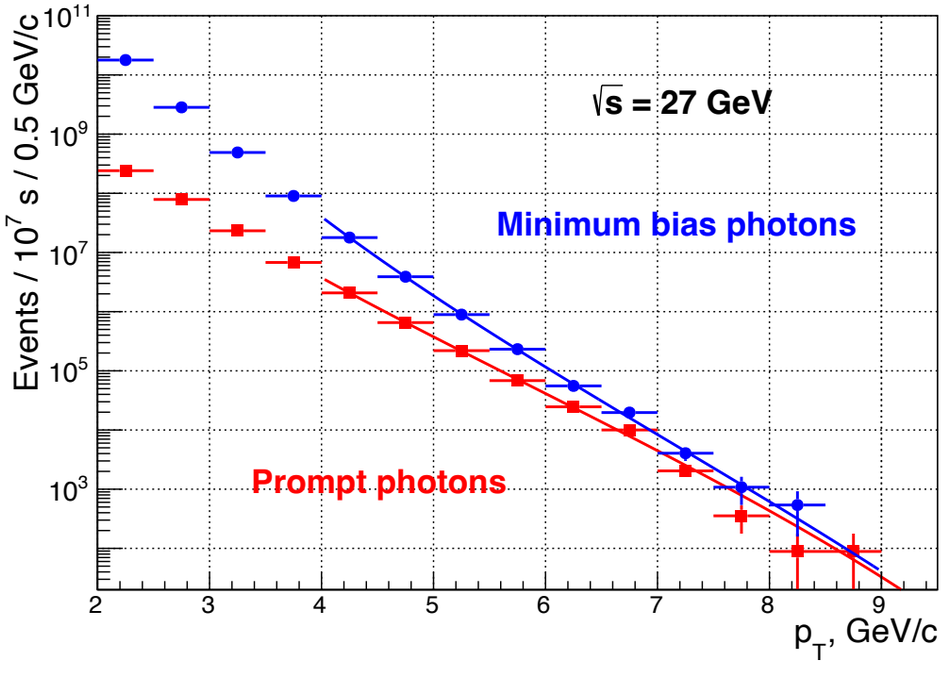


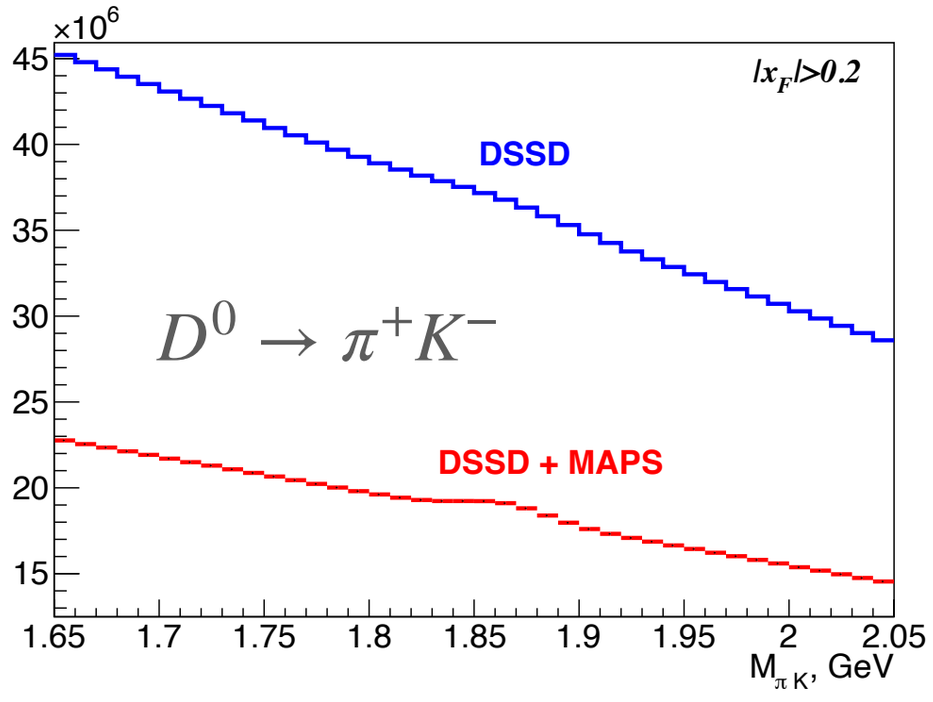
PHYSICS PERFORMANCE: GLUON PROBES (1 YEAR=10^7 S)







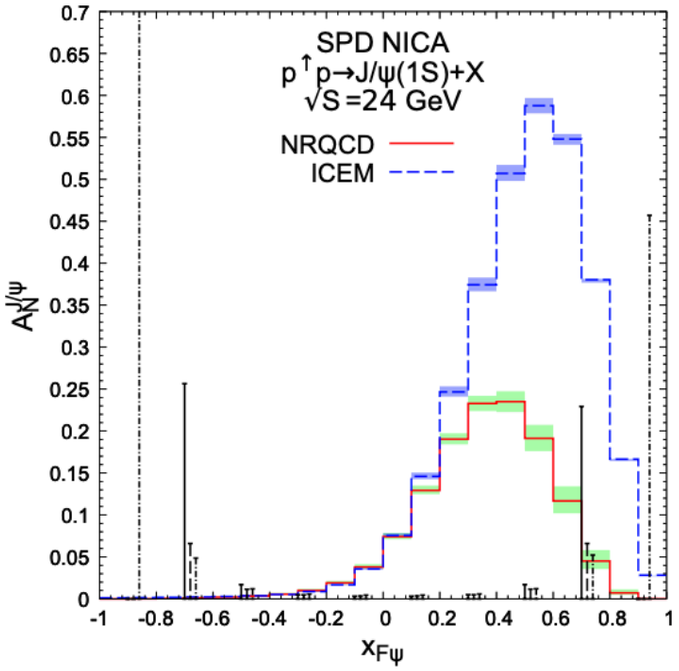




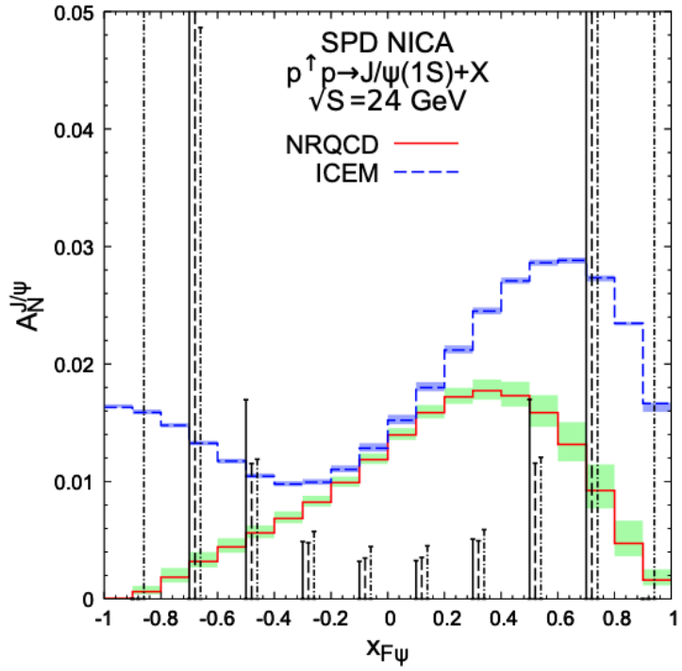
RATES FOR MAIN PROBES

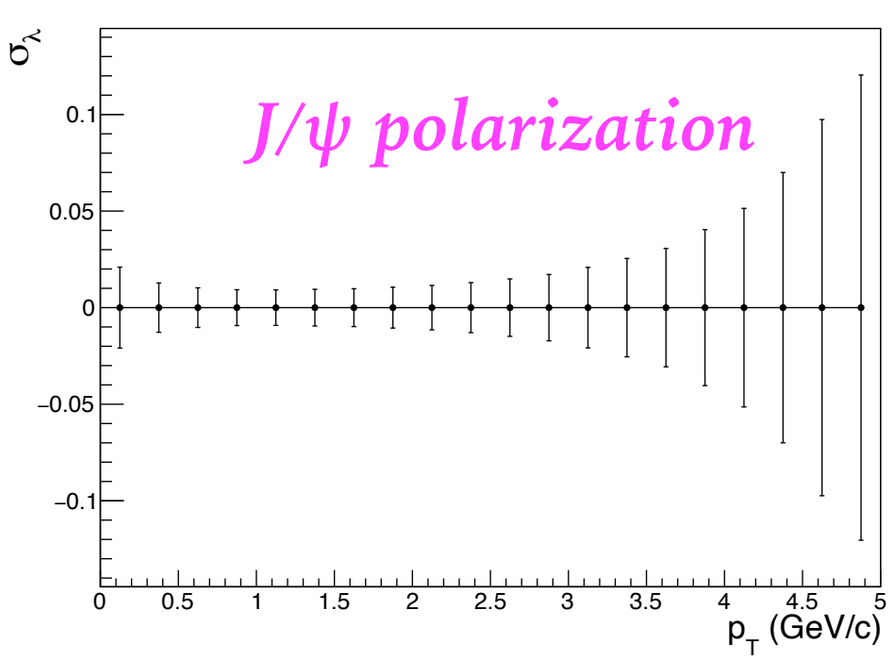
Probe	$\sigma_{27\,\mathrm{GeV}}$, nb (×BF)	$\sigma_{13.5\,\mathrm{GeV}}$, nb (×BF)	$N_{27\,\mathrm{GeV}}$, 10^6	$N_{13.5\,\mathrm{GeV}}$ 10^6
Prompt-γ ($p_T > 3$ GeV/c)	35	2	35	0.2
J/ψ	200	60		
$\to \mu^+\mu^-$	12	3.6	12	0.36
$\psi(2S)$	25	5		
$\to J/\psi\pi^+\pi^- \to \mu^+\mu^-\pi^+\pi^-$	0.5	0.1	0.5	0.01
$\to \mu^+\mu^-$	0.2	0.04	0.2	0.004
$\chi_{c1} + \chi_{c2}$	200			
$\to \gamma J/\psi \to \gamma\mu^+\mu^-$	2.4		2.4	
η_c	400			
$\to p\bar{p}$	0.6		0.6	
Open charm: $D\overline{D}$ pairs	14000	1300		
Single D-mesons				
$D^+ \to K^-2\pi^+$ ($D^- \to K^+2\pi^-$)	520	48	520	4.8
$D^0 \to K^-\pi^+$ ($\overline{D}^0 \to K^+\pi^-$)	360	33	360	3.3

PHYSICS PERFORMANCE: ACCURACIES



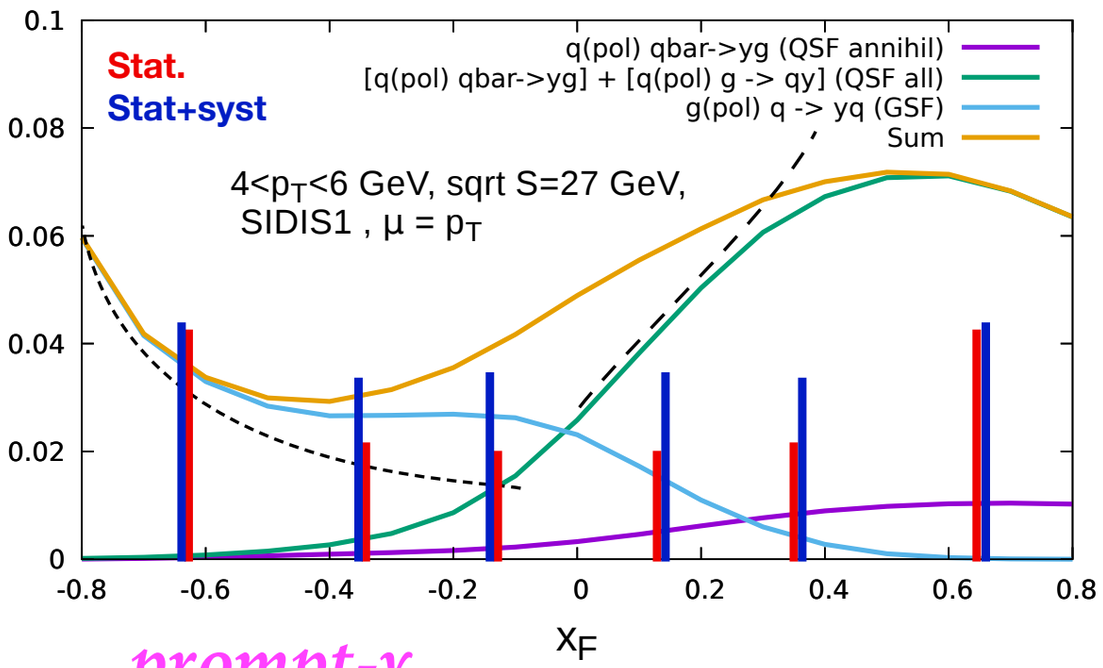
J/ψ



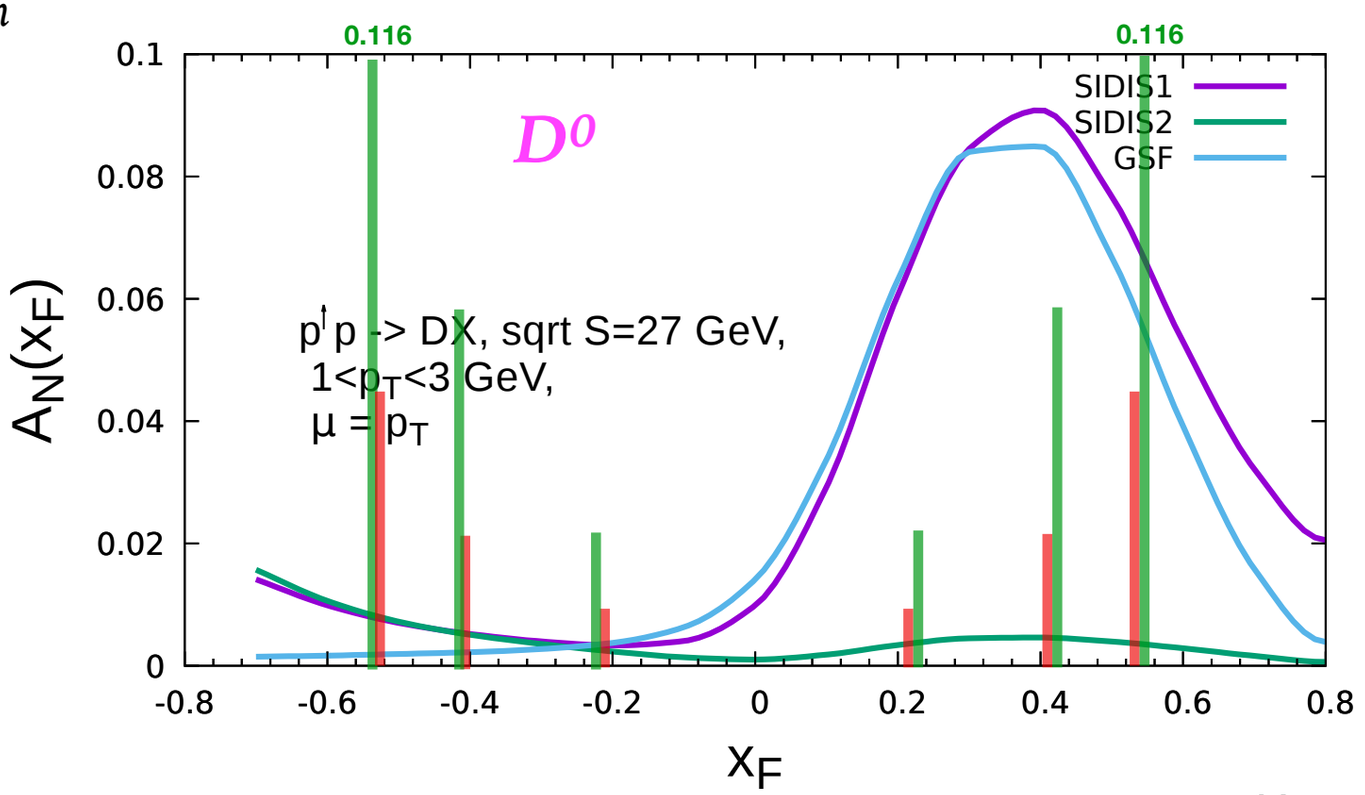


J/ψ polarization

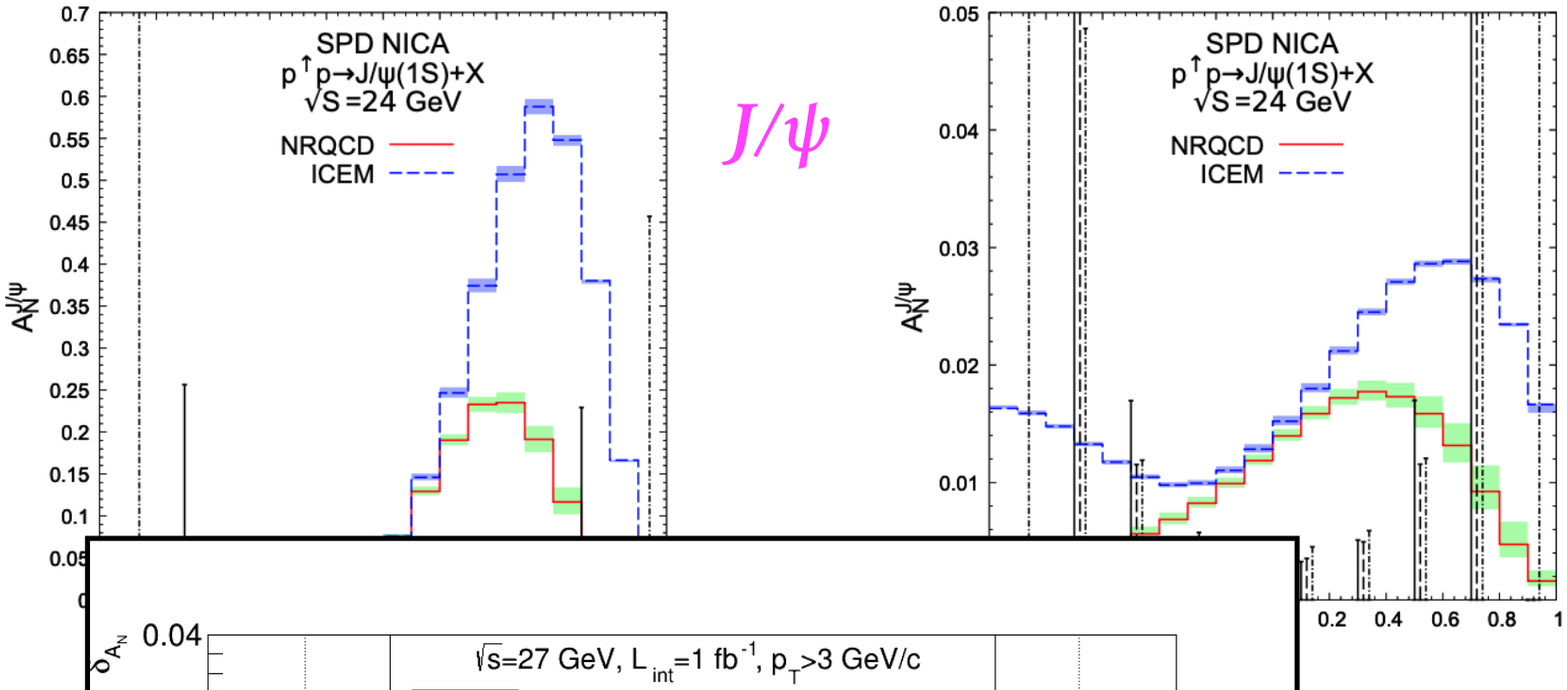
Different inputs for gluon Sivers function



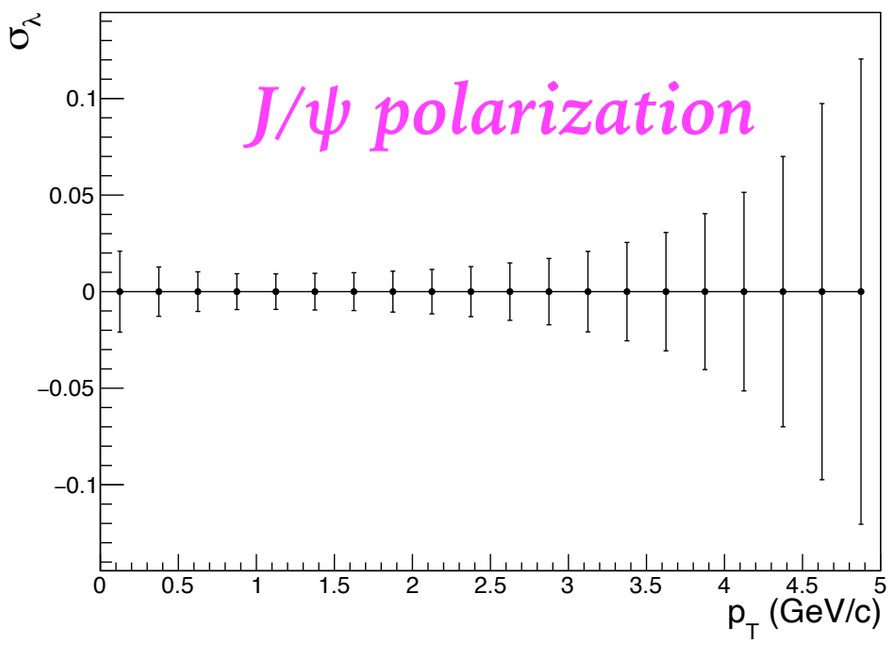
prompt-γ



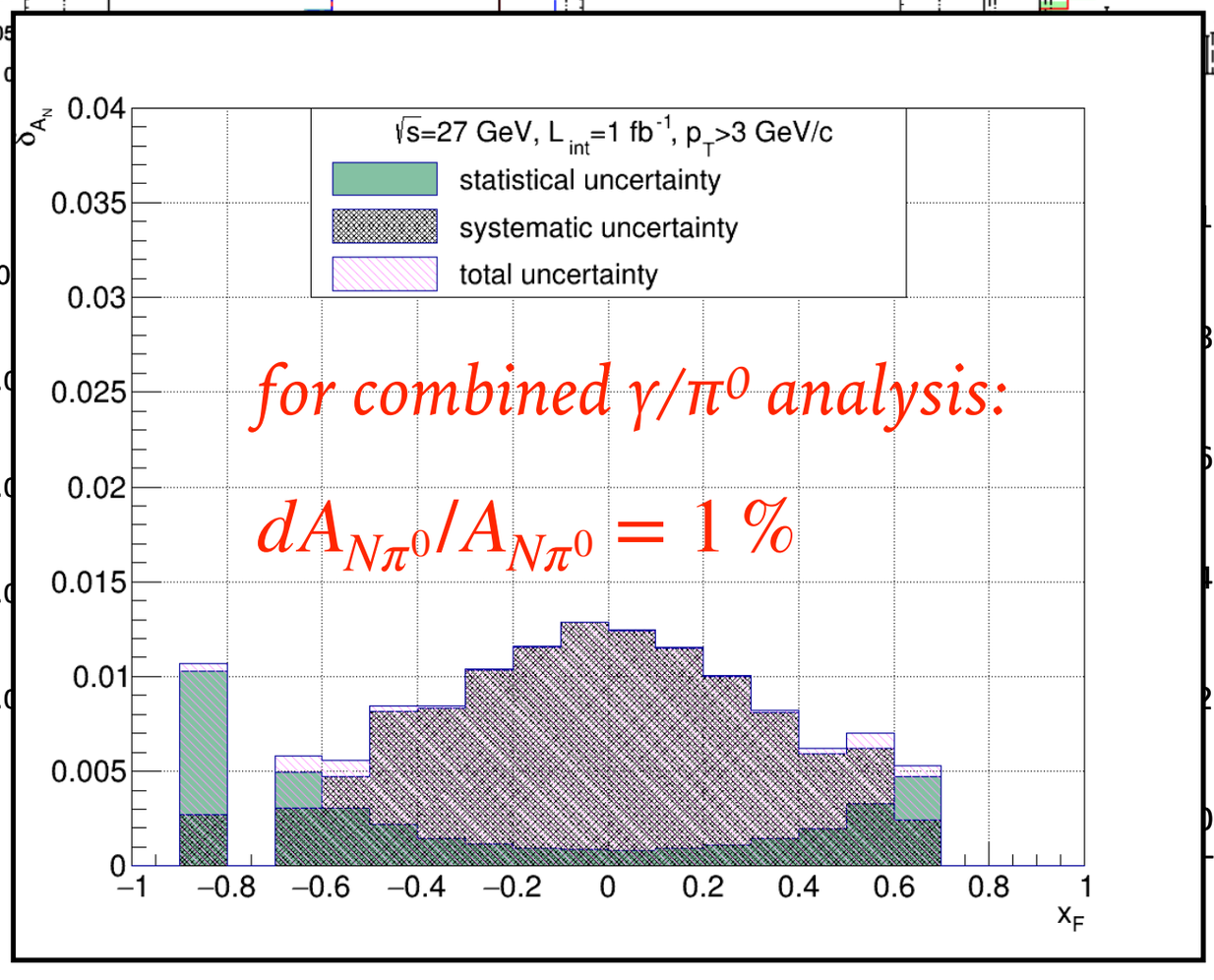
PHYSICS PERFORMANCE: ACCURACIES



J/ψ

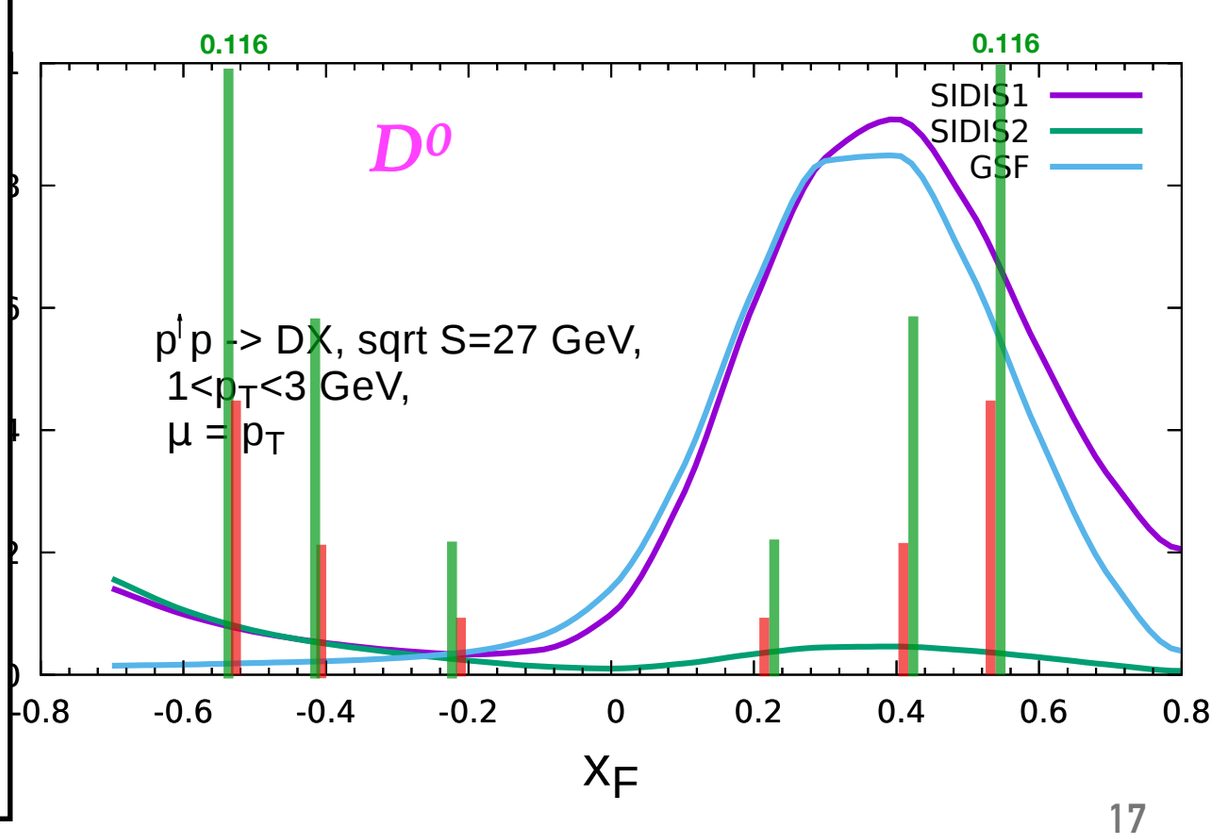


J/ψ polarization



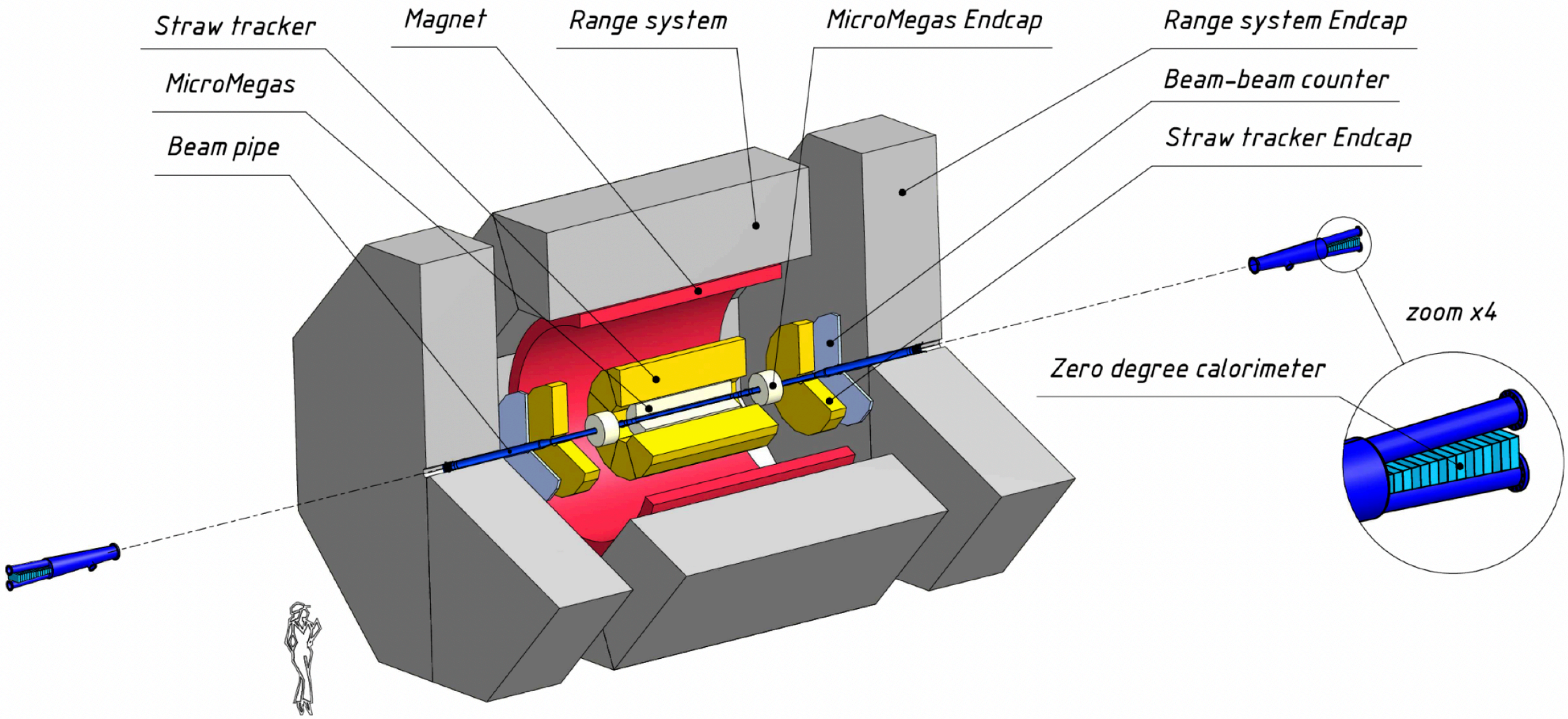
for combined γ/π^0 analysis:

$$dA_{N\pi^0}/A_{N\pi^0} = 1\ \%$$



D^0

SPD: PHASE-I



Running with reduced beam energy and luminosity

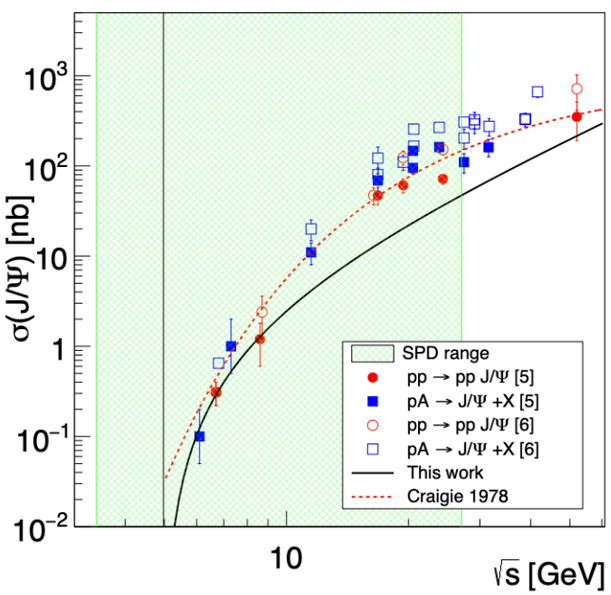
Physics of Particles and Nuclei v52, p1044–1119 (2021) arXiv:2102.08477

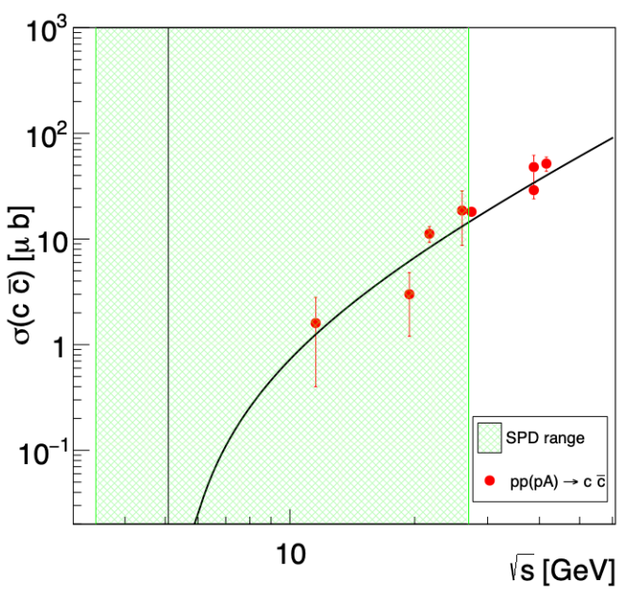
PHYSICS OF THE FIRST STAGE OF SPD RUNNING

Non-perturbative QCD — *Perturbative QCD*

$\sqrt{s}$

- Spin effects in p-p, p-d and d-d elastic scattering
- Spin effects in hyperon production
- Multiquark correlations $pp \to (6q)^* \to N\,N\,Mesons$
- Dibaryon resonances
- Physics of light and intermediate nuclei collisions
- Exclusive reactions
- Hypernuclei $dd \to K^+\,K^+\,{}^{4}_{\Lambda\Lambda}\mathrm{n}$;
- Open charm and charmonia near threshold





Reduced luminosity and beam energy

- Auxiliary studies for astrophysical experiments
- …

SUMMARY

- The **Spin Physics Detector** at the NICA collider is a universal facility for comprehensive study of polarized and unpolarized **gluon content of proton and deuteron**; in polarized high-luminosity **p-p** and **d-d** collisions at $\sqrt{s} \leq 27\ GeV$;
- Complementing main probes such as **charmonia** (J/ψ and higher states), **open charm** and **prompt photons** will be used for that;
- SPD can contribute significantly to investigation of
  - gluon helicity;
  - gluon-induced TMD effects (Sivers and Boer-Mulders);
  - unpolarized gluon PDFs at high-x in proton and deuteron;
  - gluon transversity in deuteron;
  - …
- Comprehensive physics program for the first period of data taking: spin effects in p-p, p-d and d-d elastic scattering, spin effects in hyperon production, multiquark correlations, dibaryon resonances, physics of light and intermediate nuclei collisions, exclusive reactions, hypernuclei, open charm and charmonia near threshold, etc.;
- **The SPD gluon physics program is complementary to the other intentions to study the gluon content of nuclei (RHIC, AFTER, LHC-Spin, EIC, JLab experiments) and mesons (AMBER, EIC);**
- SPD CDR could be found at **arXiv:2102.00442** for more details;
- More information could be found at http://spd.jinr.ru .