

# SPD EXPERIMENT AT NICA COLLIDER

*Alexey Guskov (JINR) on behalf of the SPD collaboration*

22<sup>nd</sup> edition  
**PANIC Lisbon Portugal**  
Particles and Nuclei International Conference

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[Alexey.Guskov@cern.ch](mailto:Alexey.Guskov@cern.ch)

# THE **JOINT INSTITUTE FOR NUCLEAR RESEARCH**, DUBNA, RUSSIA

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The **Joint Institute for Nuclear Research** is an international intergovernmental scientific research organization in the science city Dubna of the Moscow region (Russia)

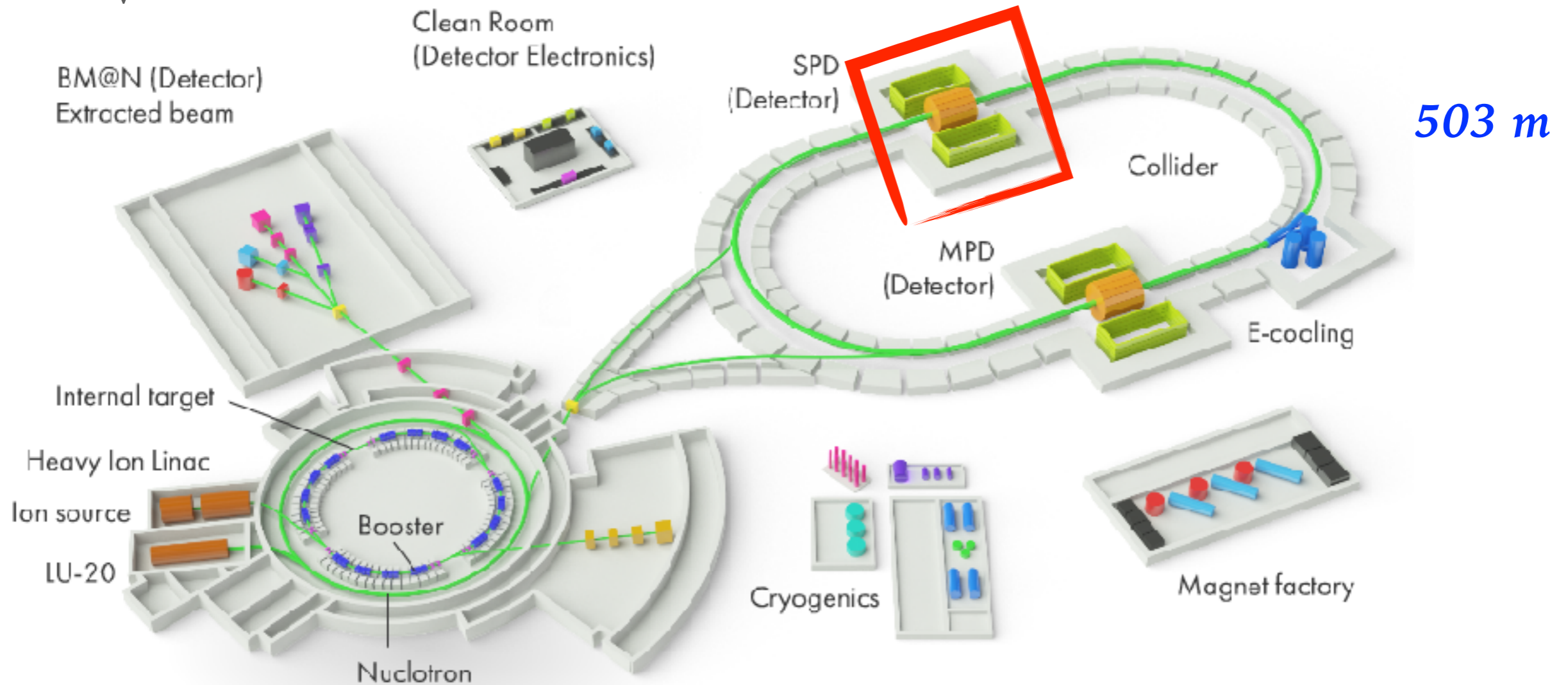
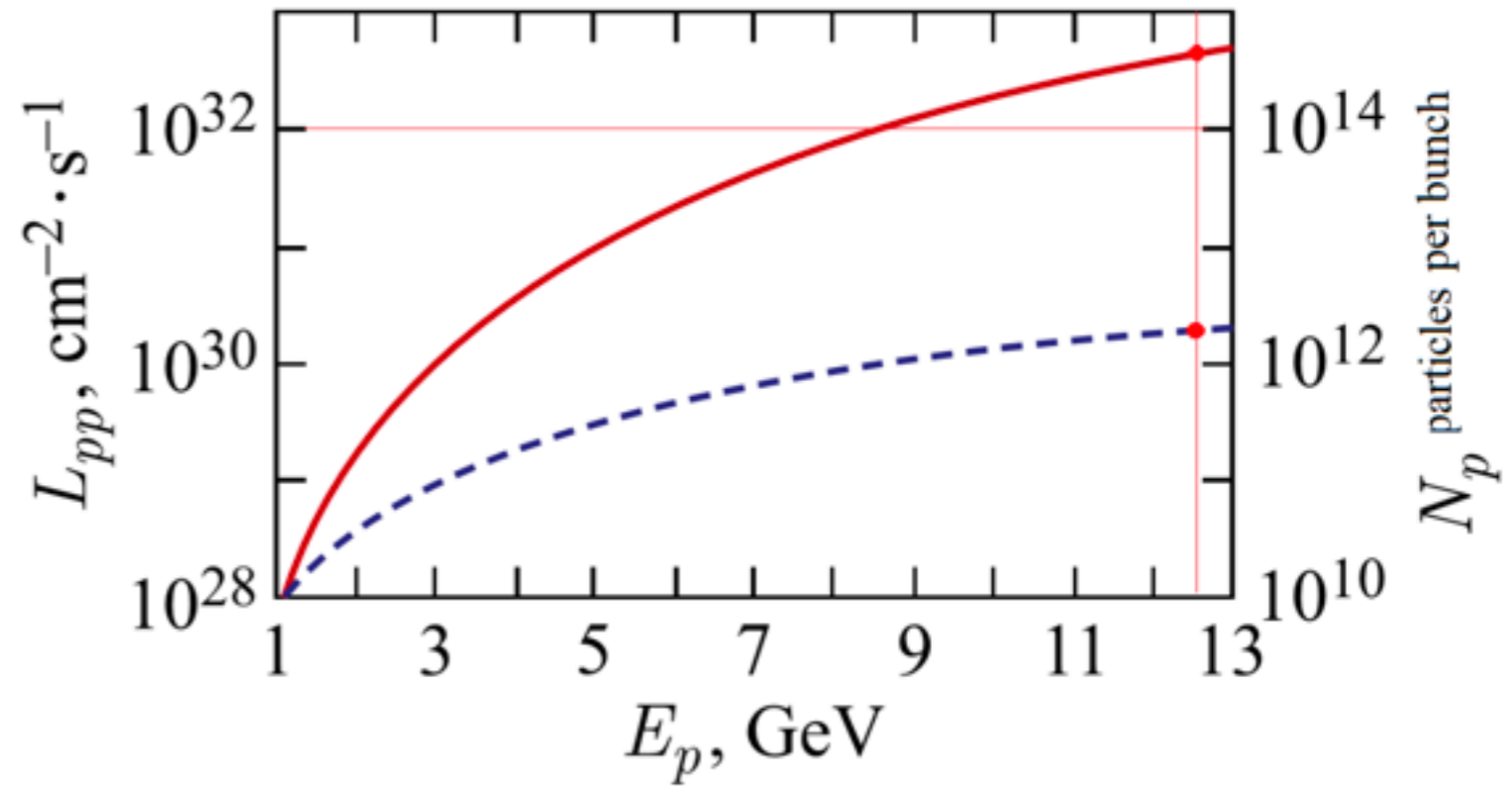
# SPD AT NICA

NICA - Nuclotron-based Ion Collider fAcility

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

$d^\uparrow d^\uparrow : \sqrt{s} \leq 13.5 \text{ GeV}$  **U, L, T**

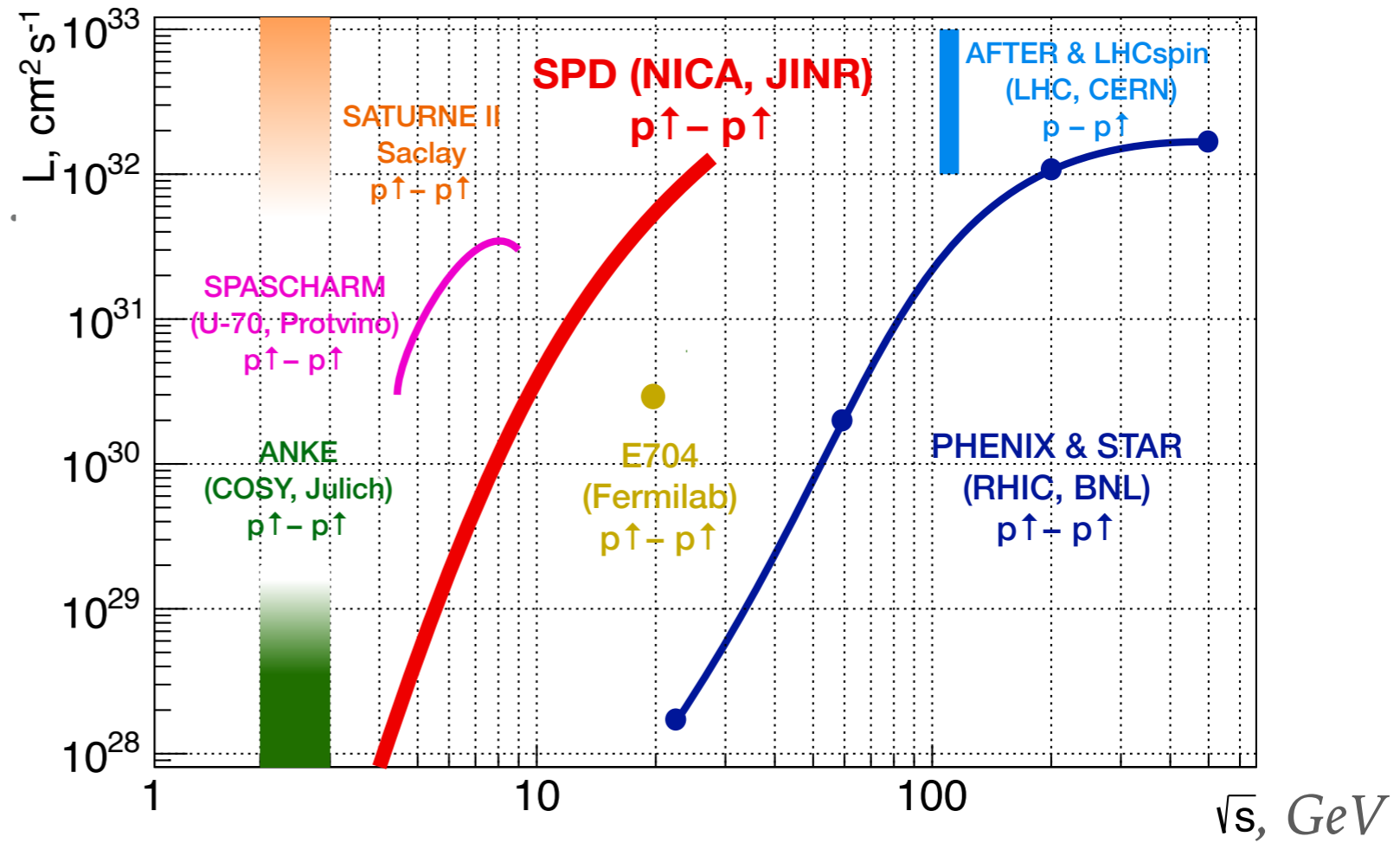
$d^\uparrow p^\uparrow : \sqrt{s} \leq 19 \text{ GeV}$  **|P| > 70%**





# SPD & OTHERS

*In the  $p^\uparrow p^\uparrow$  mode:*

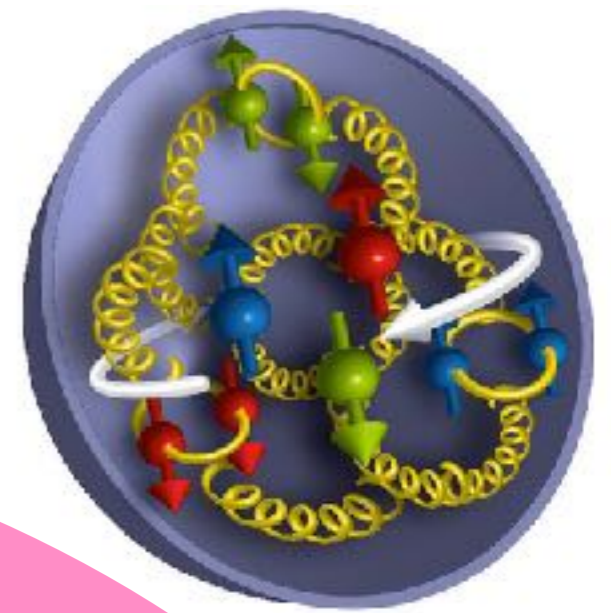


Experimental facility	SPD @NICA	RHIC	EIC	AFTER @LHC	LHCspin
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^\uparrow - p^\uparrow$ <b><math>d^\uparrow - d^\uparrow</math></b> $p^\uparrow - d, p - d^\uparrow$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

*In the  $d^\uparrow d^\uparrow$  mode we are unique*

# CONCEPT OF THE **SPD** PHYSICS PROGRAM

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

Charmonia

Prompt photons

Open charm


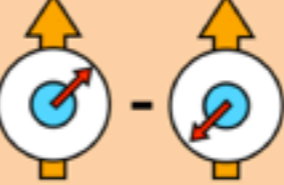
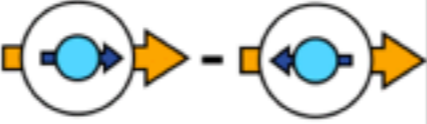
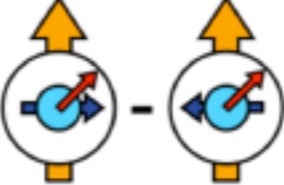

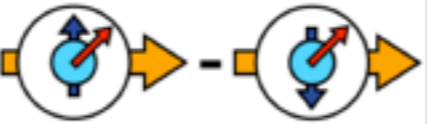
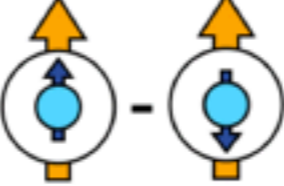
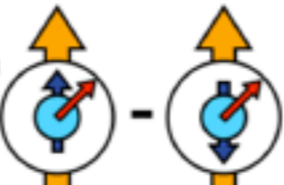
Other spin-related phenomena

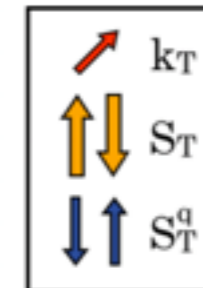
Other physics

# POLARIZED PARTONIC STRUCTURE

## Nucleon Spin Polarization

Quark Spin Polarization

	U	L	T
U	$f_1$  Number Density		$f_{1T}^{q\perp}$  Sivers
L		$g_{1L}^q$  Helicity	$g_{1T}^q$  Worm-Gear T
T	$h_1^{q\perp}$  Boer-Mulders	$h_L^{q\perp}$  Worm-Gear L	$h_1^q$  Transversity $h_{1T}^{q\perp}$  Pretzelosity



# PARTONIC STRUCTURE OF PROTON

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

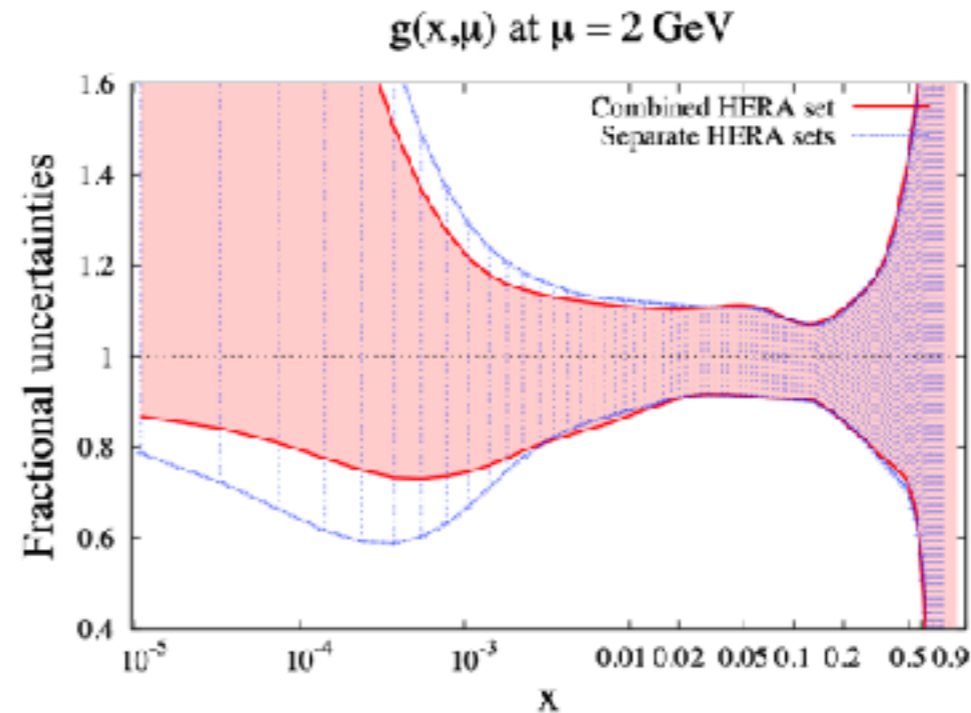
$$A_{TT}(x_F, p_T) \quad A_N(x_F, p_T)$$

Spin crisis:

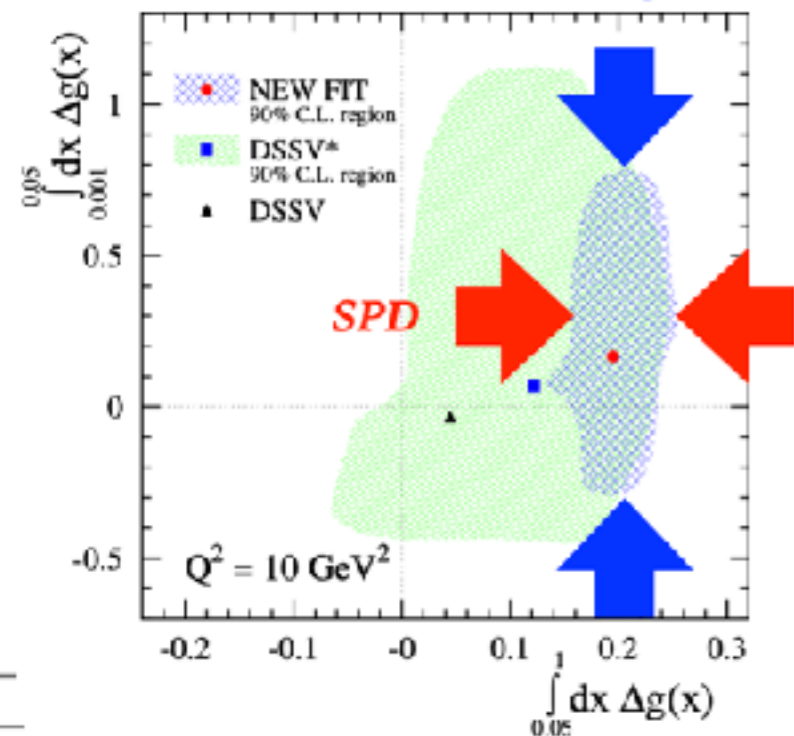
Gluon helicity



Unpolarized gluons in proton at high  $x$ :



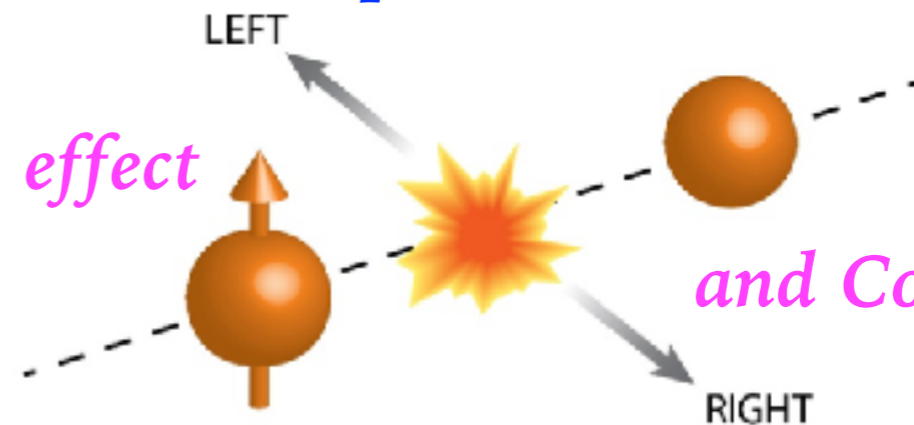
Phys.Rev.Lett. 113 (2014) 1, 012001 EIC



Gluon and quark TMD PDFs:

Sivers effect

and Collins effect



Spin-dependent fragmentation functions



# ... AND DEUTERON

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

Nonbaryonic content of deuteron:

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

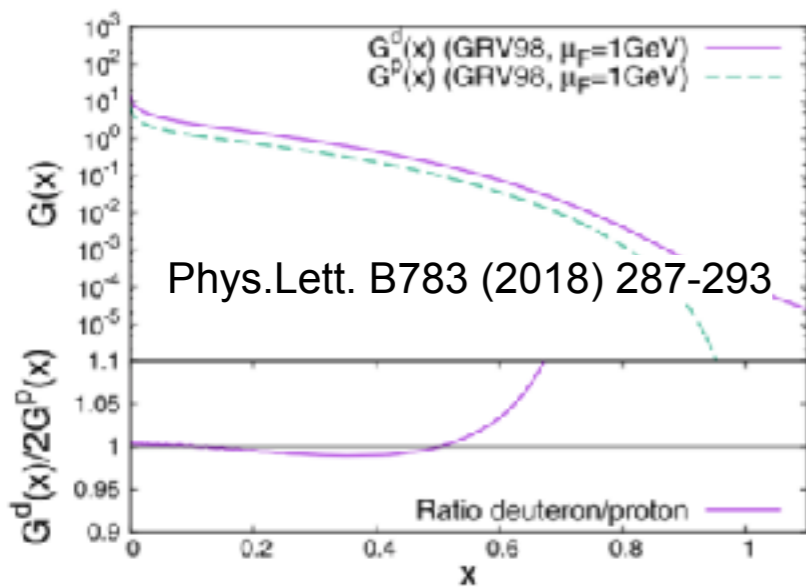
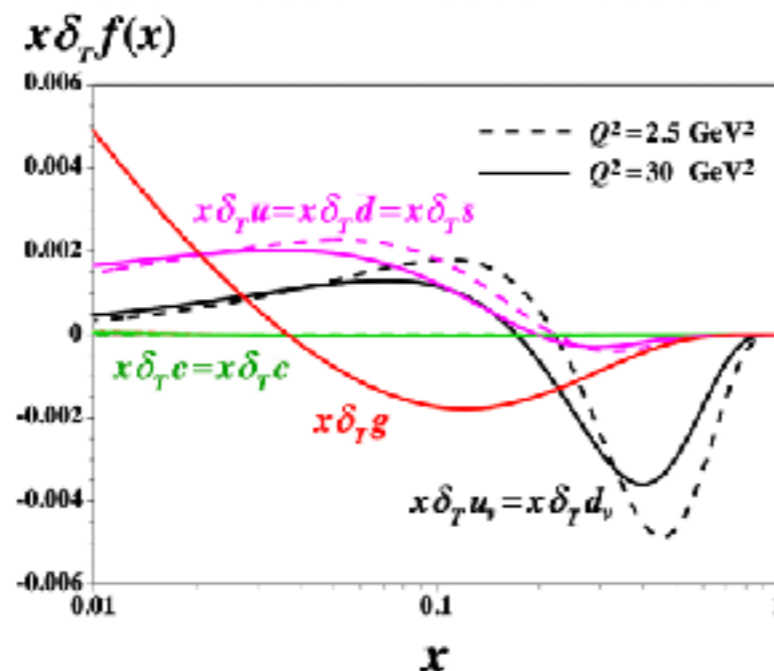
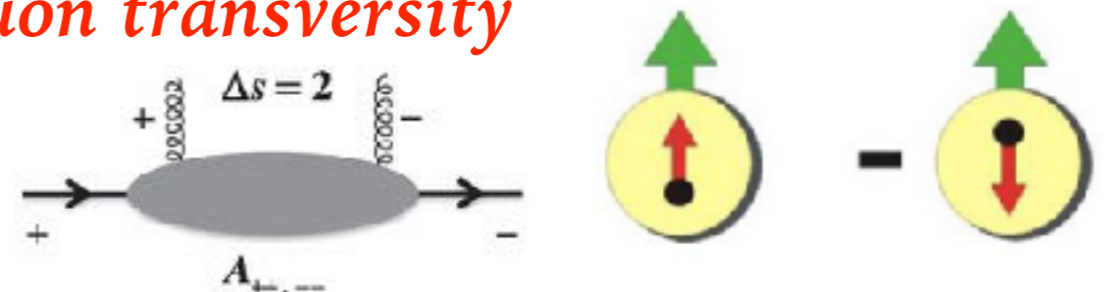


Fig. 6. Gluon PDF in the deuteron and in the nucleon.

Unpolarized  
gluons at high x:



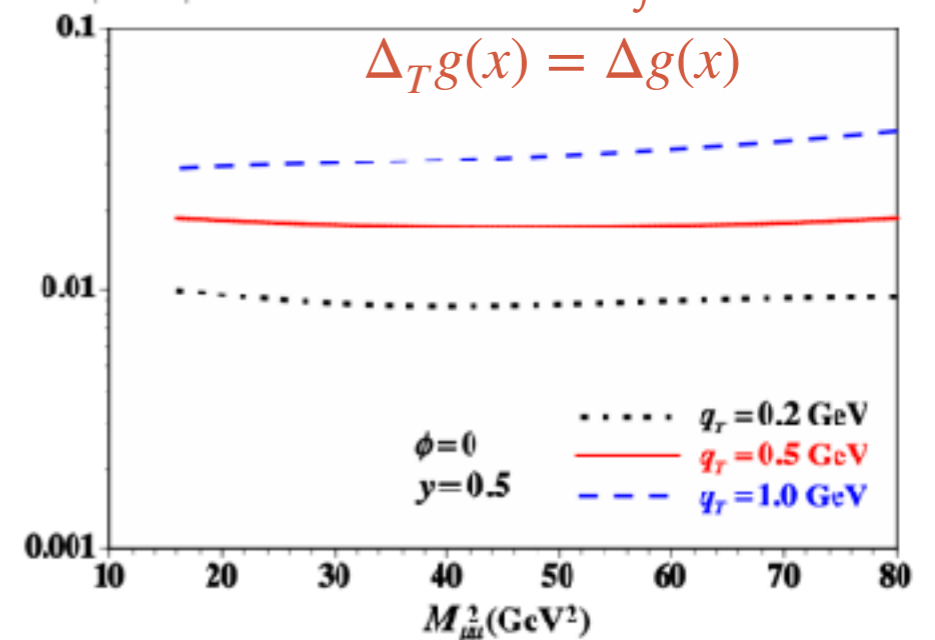
Gluon transversity



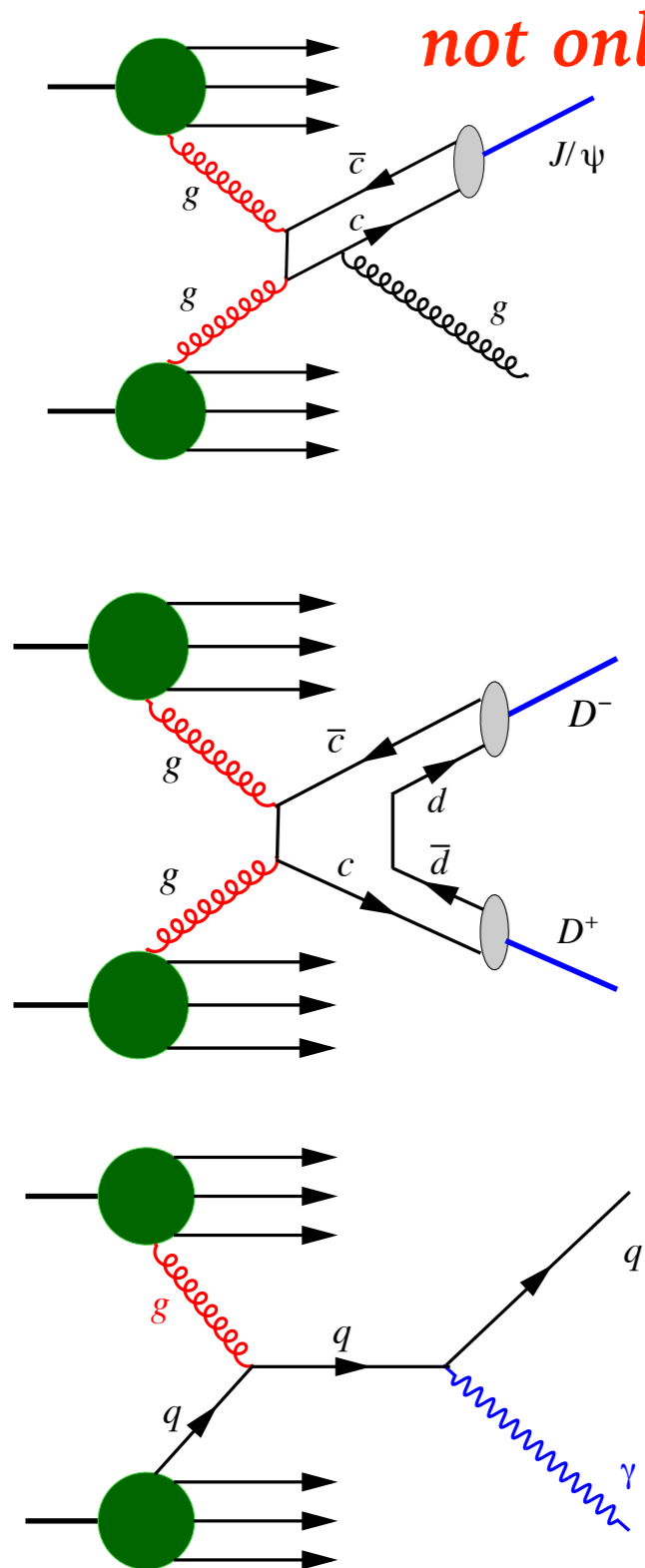
Tensor PDFs

Sh. Kumano for DY:

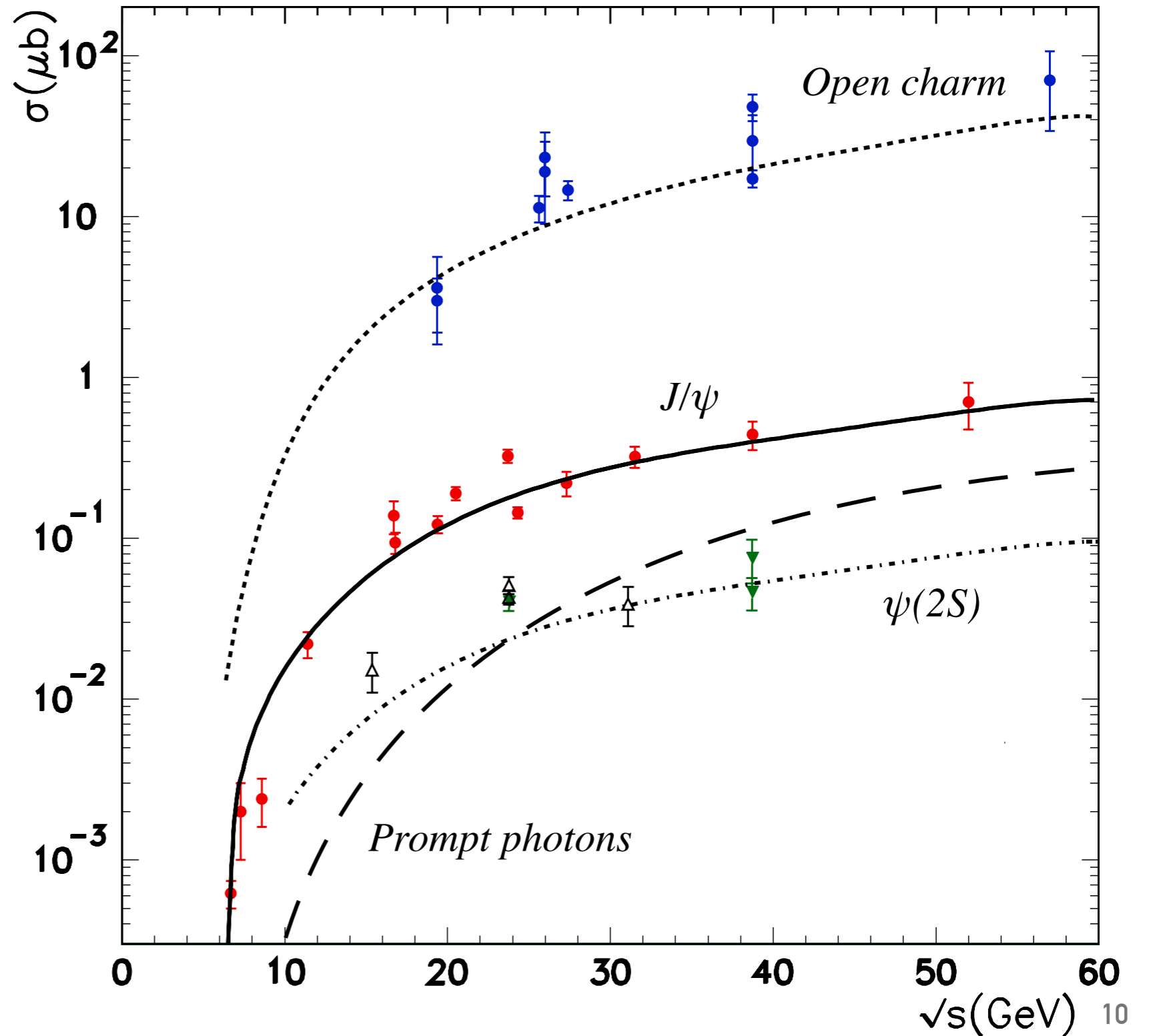
$$\Delta_T g(x) = \Delta g(x)$$



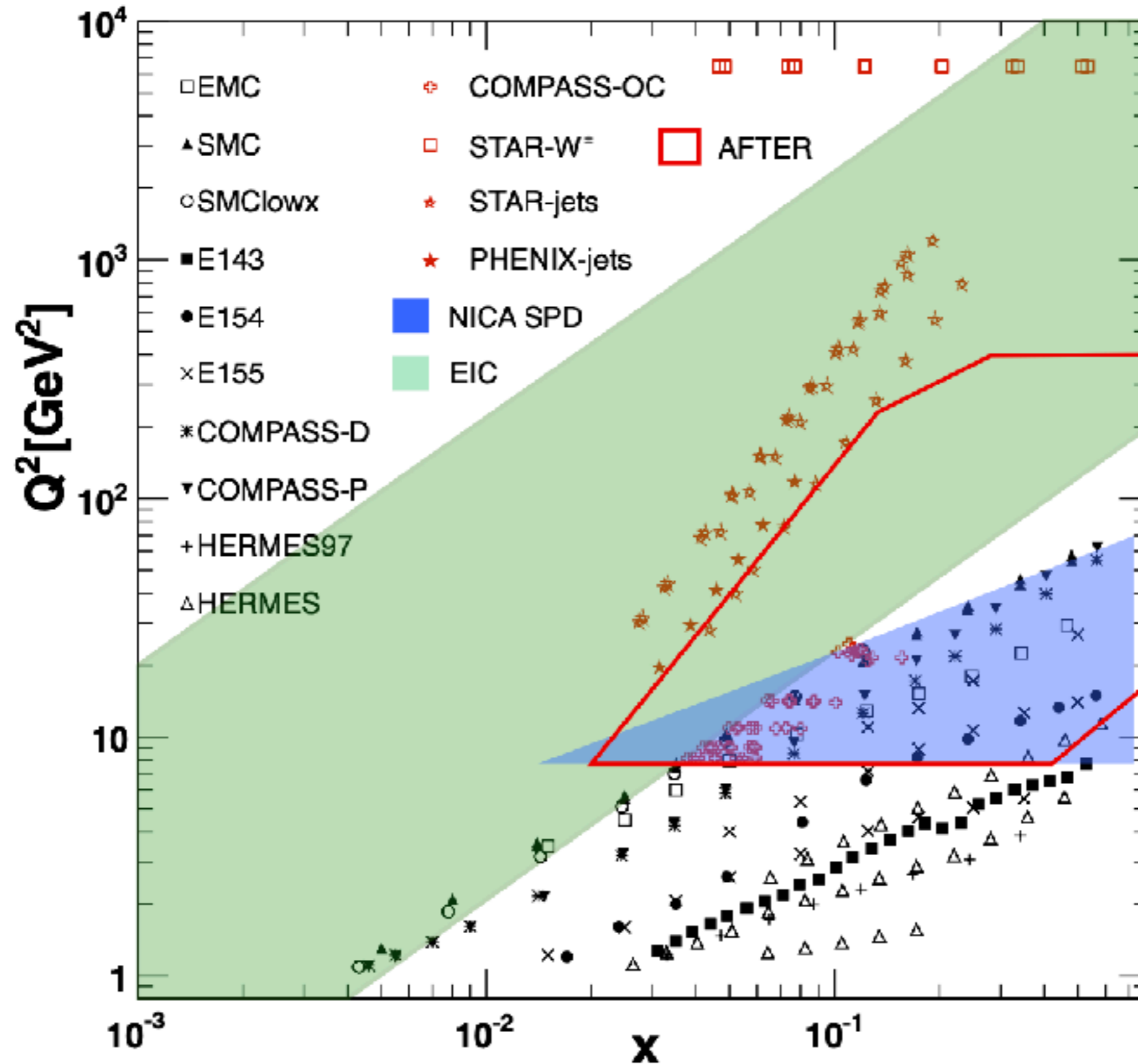
# GLUON PROBES AT SPD



$$\sigma = PDF_1 \otimes PDF_2 \otimes \hat{\sigma}_{12}$$



# KINEMATIC RANGE



# PHYSICS OF THE FIRST STAGE OF **SPD** RUNNING

*Non-perturbative QCD*

*Perturbative QCD*

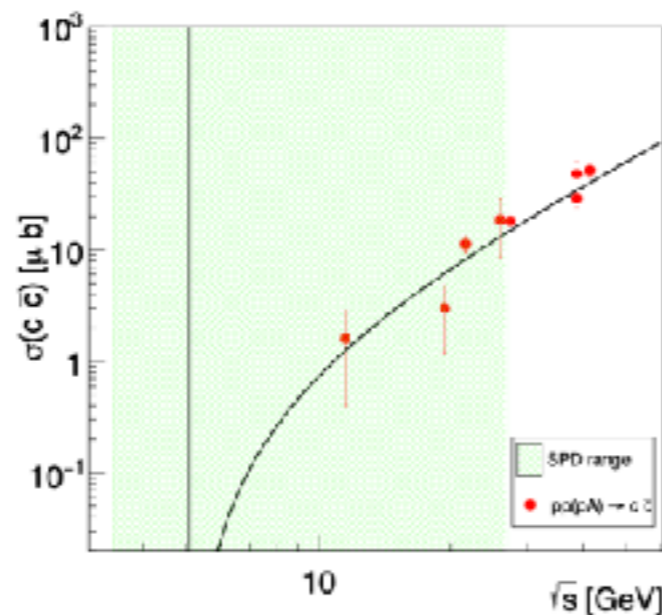
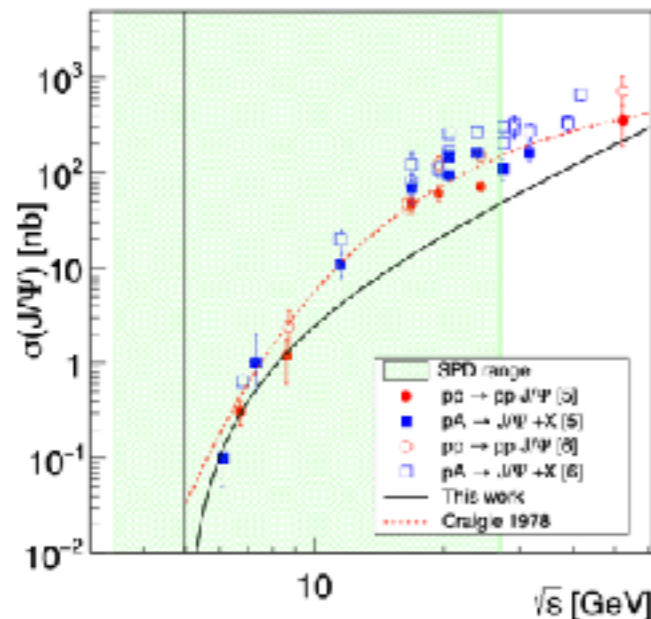
- Spin effects in p-p, p-d and d-d elastic scattering
- Spin effects in hyperon production
- Multiquark correlations
- Dibaryon resonances
- Physics of light and intermediate nuclei collisions
- Exclusive reactions
- Hypernuclei
- Open charm and charmonia near threshold

$$pp \rightarrow (6q)^* \rightarrow NN \text{ Mesons,}$$

$$dd \rightarrow K^+ K^+ \Lambda\Lambda^4 n,$$

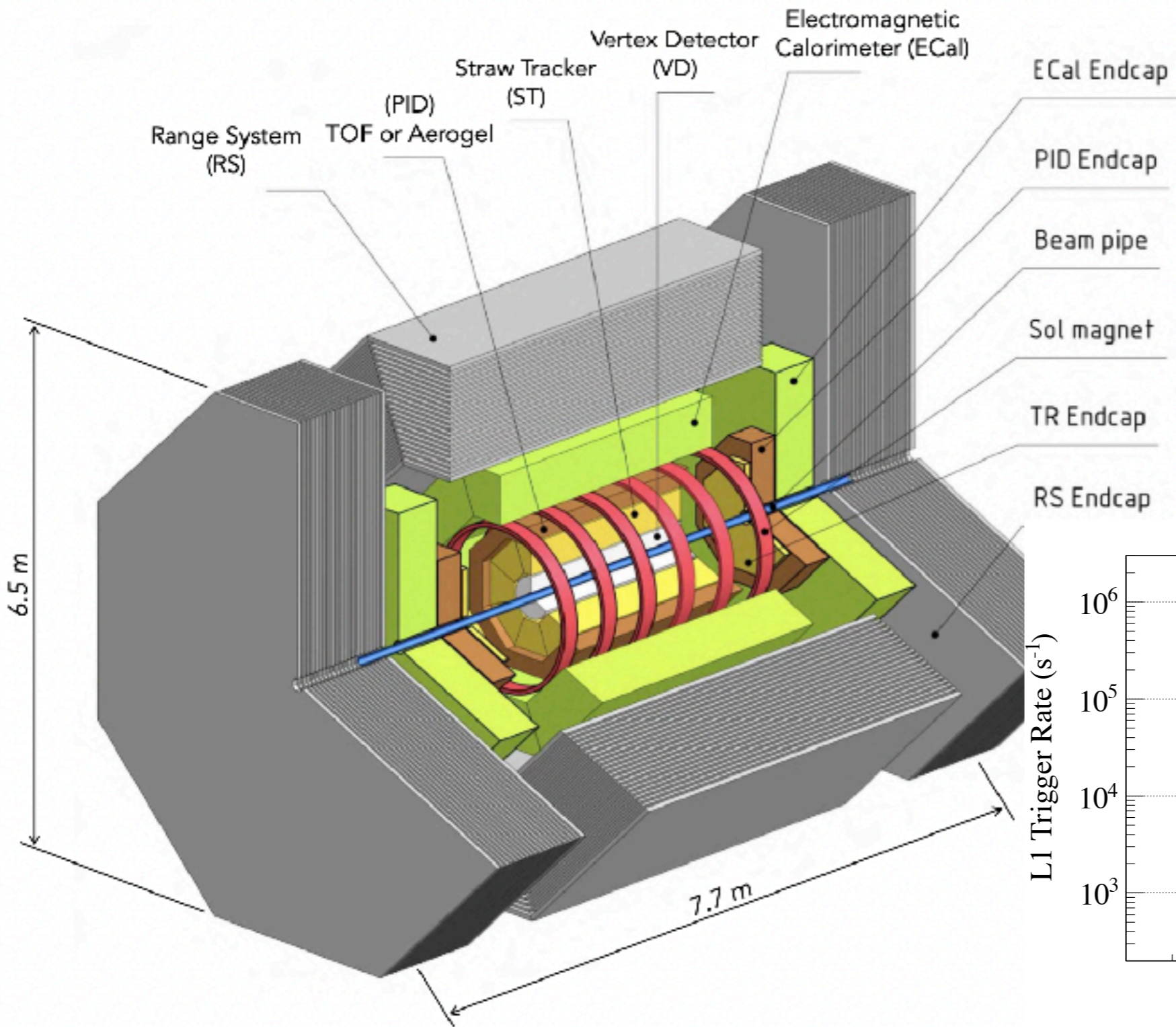
$\sqrt{s}$

*Reduced luminosity  
and beam energy.*

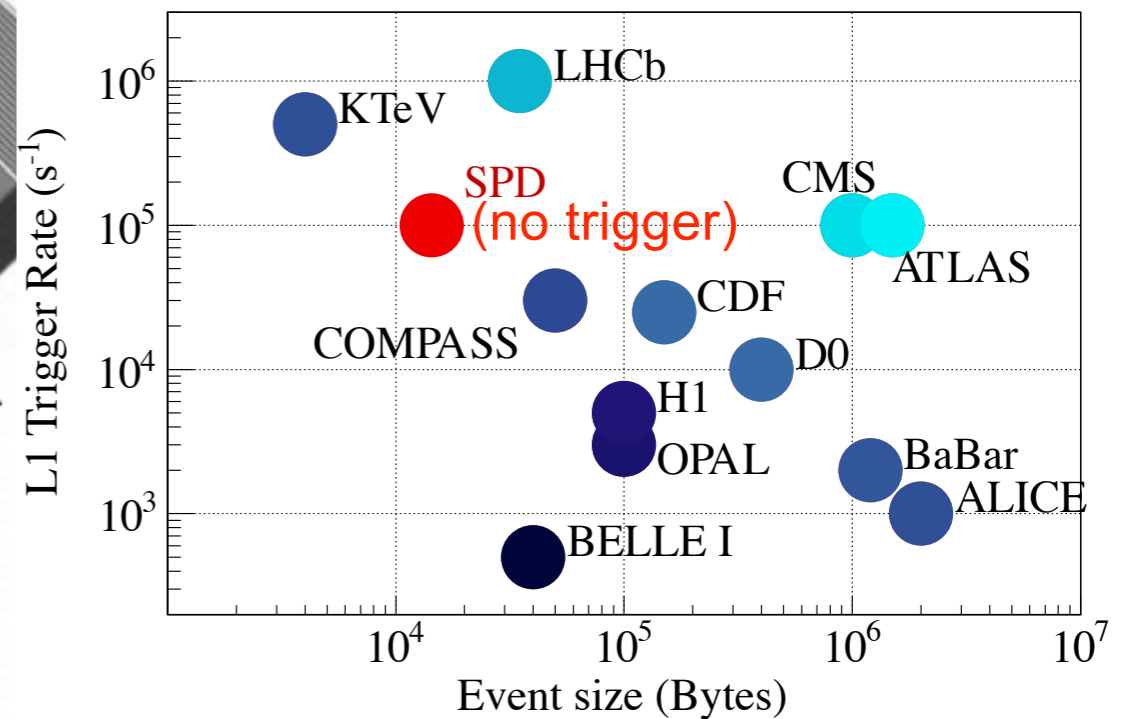


- Auxiliary measurements for Dark Matter search in astrophysical experiments
- ...

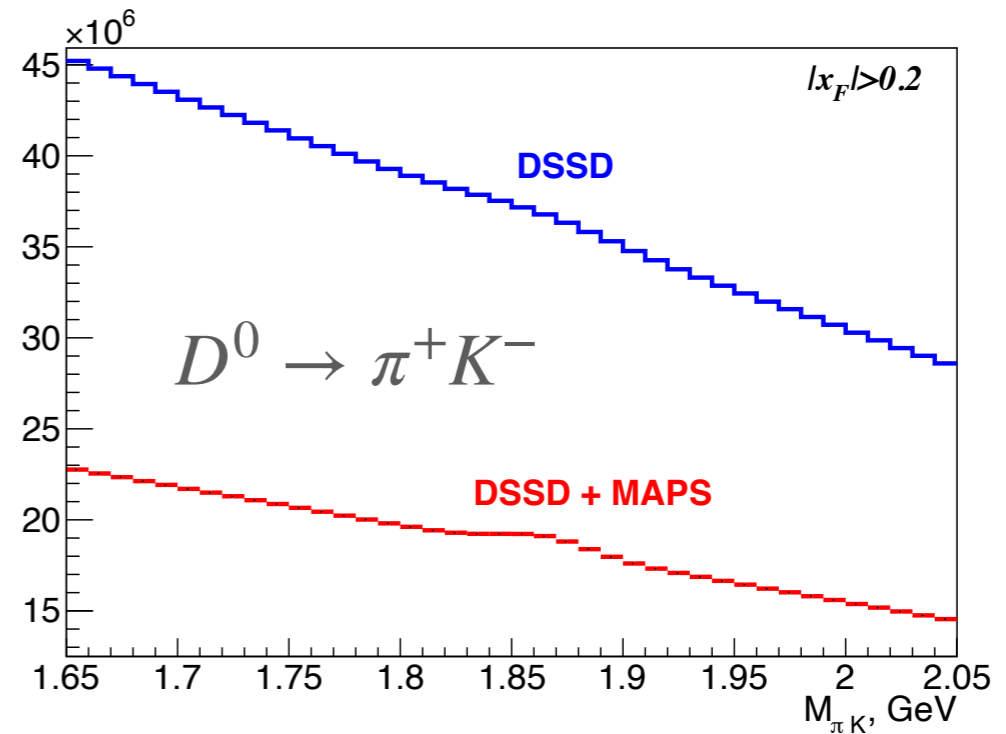
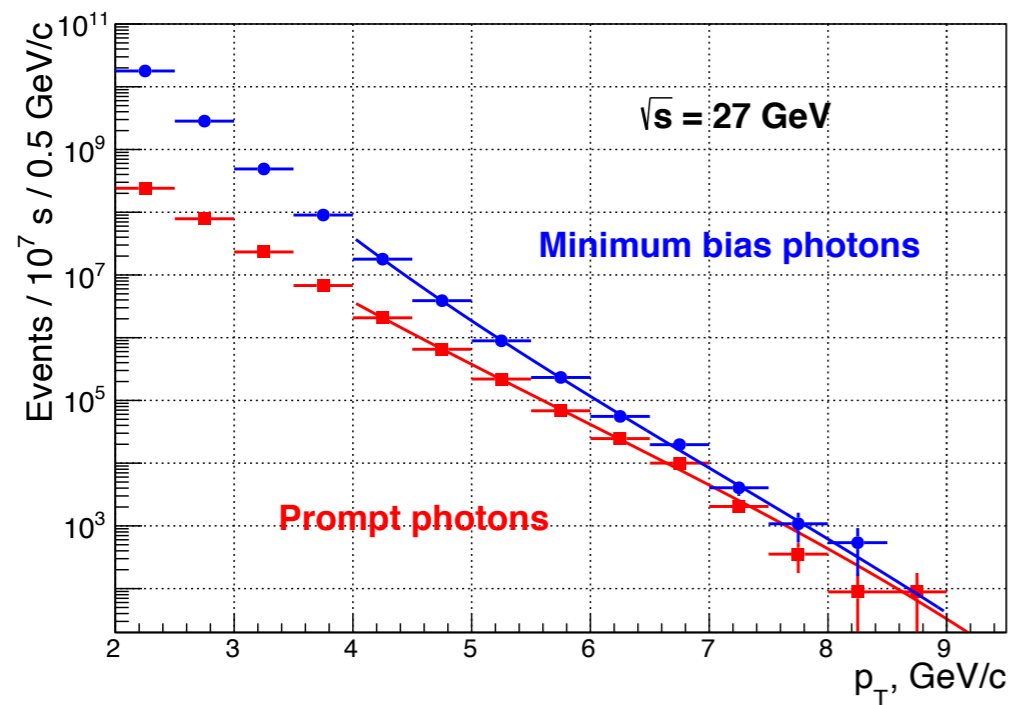
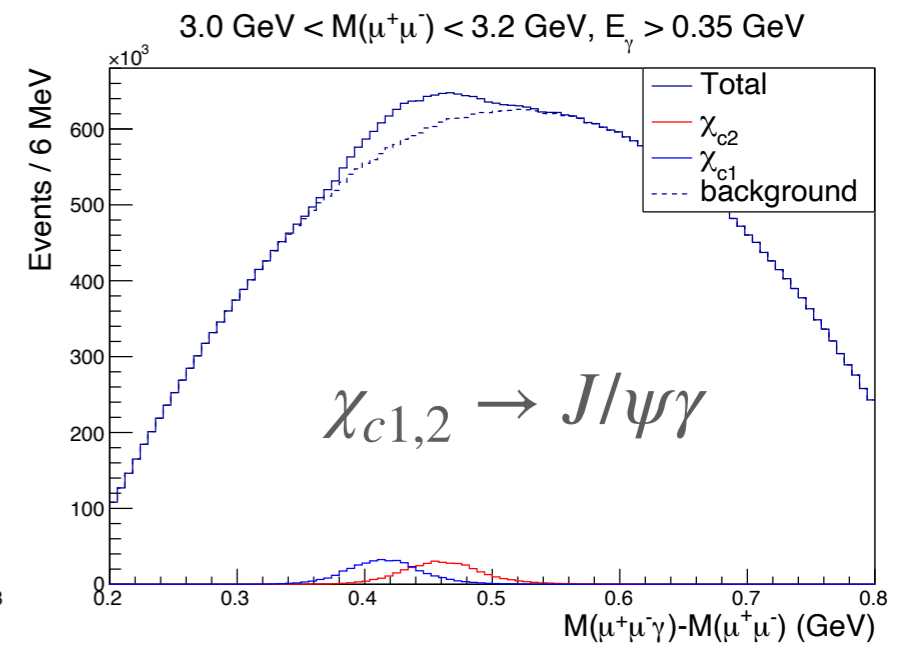
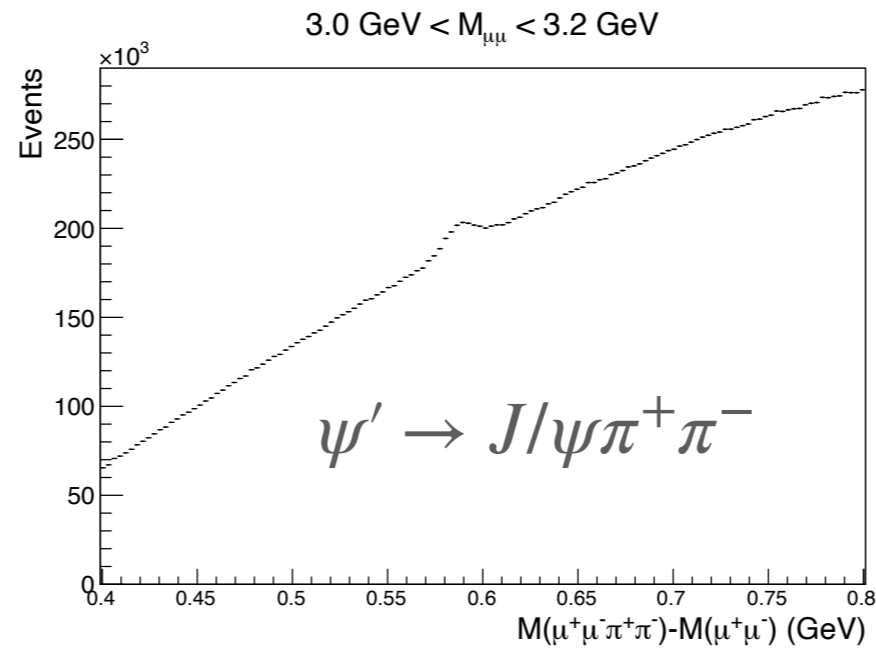
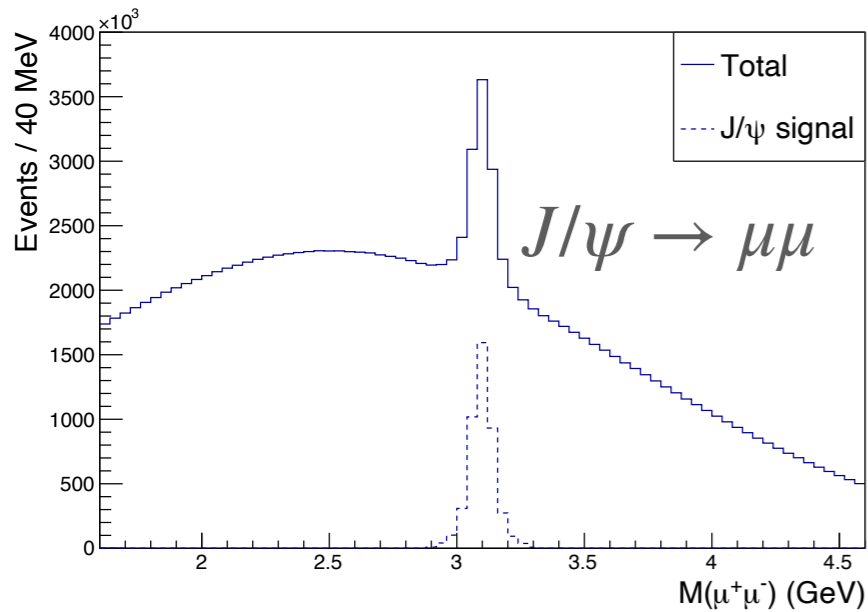
# SPD DETECTOR



*No hardware triggers to avoid possible bias!*



# PHYSICS PERFORMANCE: GLUON PROBES (1 YEAR=10<sup>7</sup> S)



# SPD INTERNATIONAL COLLABORATION

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*32 institutes from 14 states, ~300 members*

*The SPD international collaboration is forming actively*



*SPD **CDR** was issued in the beginning of 2021: [arXiv:2102.00442](https://arxiv.org/abs/2102.00442)*

*CDR is now under expertise of the international **Detector Advisory Committee***

*First version of the SPD **TDR** should be presented in 2022*

# SUMMARY

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- 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  $\sqrt{s} \leq 27 \text{ GeV}$ ;
- Complementing main probes such as **charmonia** ( $J/\psi$  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**;
- The **SPD** gluon physics program is **complementary** to the other intentions to study the gluon content of nuclei (**RHIC, AFTER, LHC-Spin, EIC**) and mesons (**COMPASS++/AMBER, EIC**);
- SPD CDR could be found at [arXiv:2102.00442](https://arxiv.org/abs/2102.00442) for more details;
- More information could be found at <http://spd.jinr.ru> .