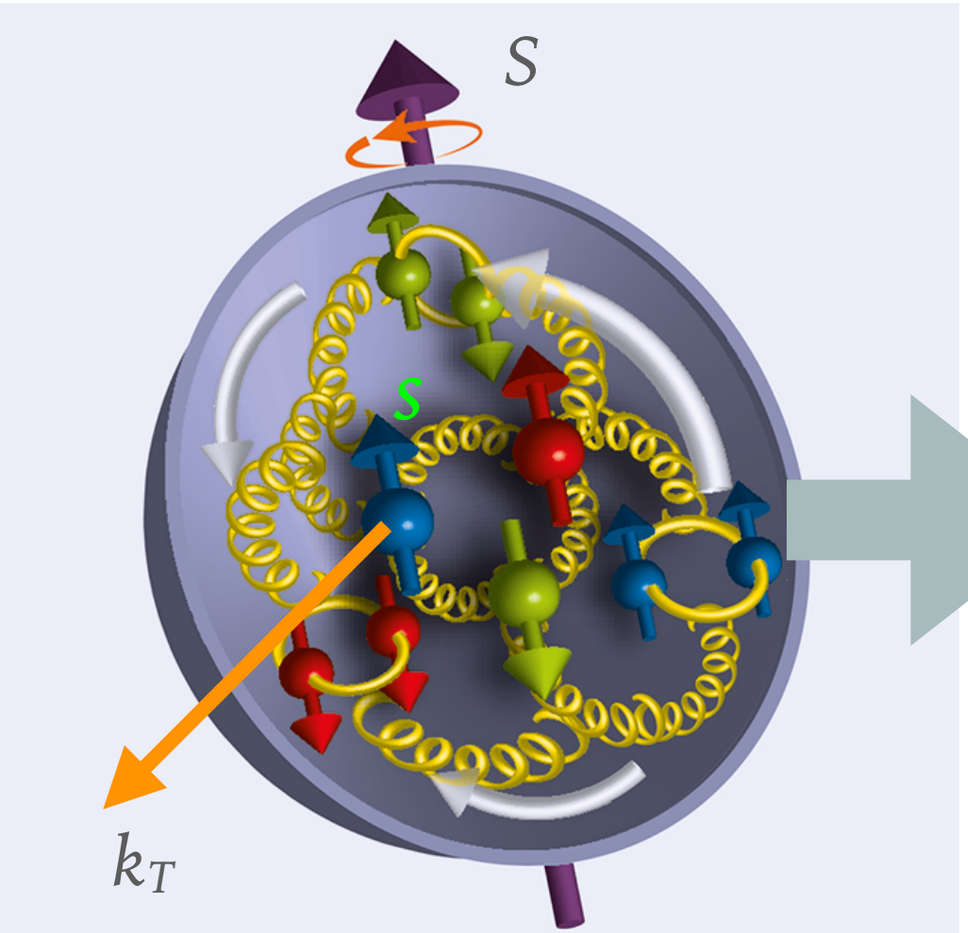
Проект SPD

Руководитель проекта Гуськов А.В.
Зам. руководителя проекта Ладыгин В.П.

А. Гуськов **24.3.2022**

SPIN STRUCTURE OF NUCLEON



QUARKS	*unpolarized*	*chiral*	*transverse*
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_{1T}, $h_{1T}^\perp$

GLUONS	*unpolarized*	*circular*	*linear*
U	f_1^g		$h_1^{\perp g}$
L		g_{1L}^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	h_{1T}^g, $h_{1T}^{\perp g}$

Momentum of proton

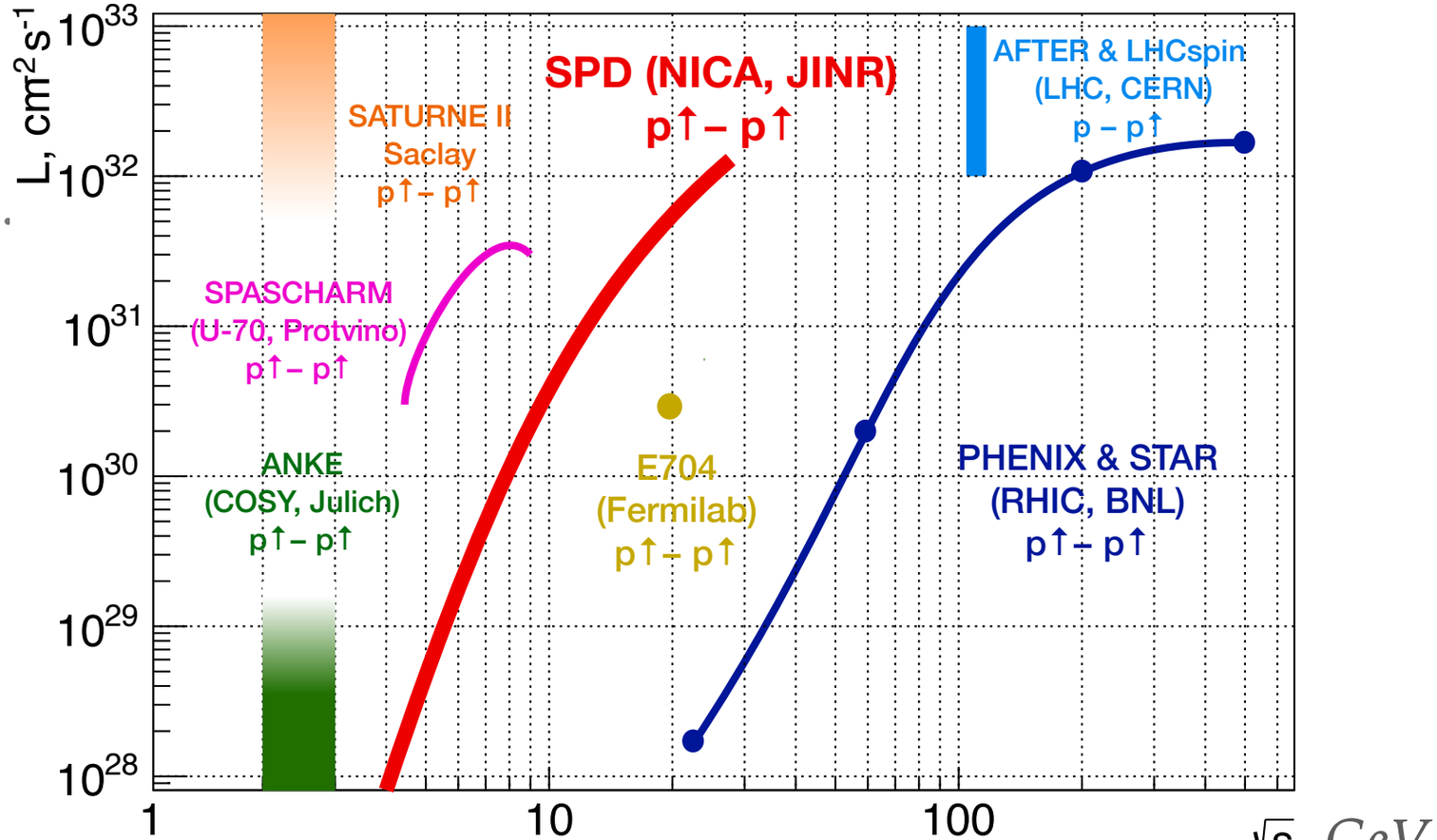
Spin of proton

Spin of parton

Transverse momentum of parton

SPD & OTHERS

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

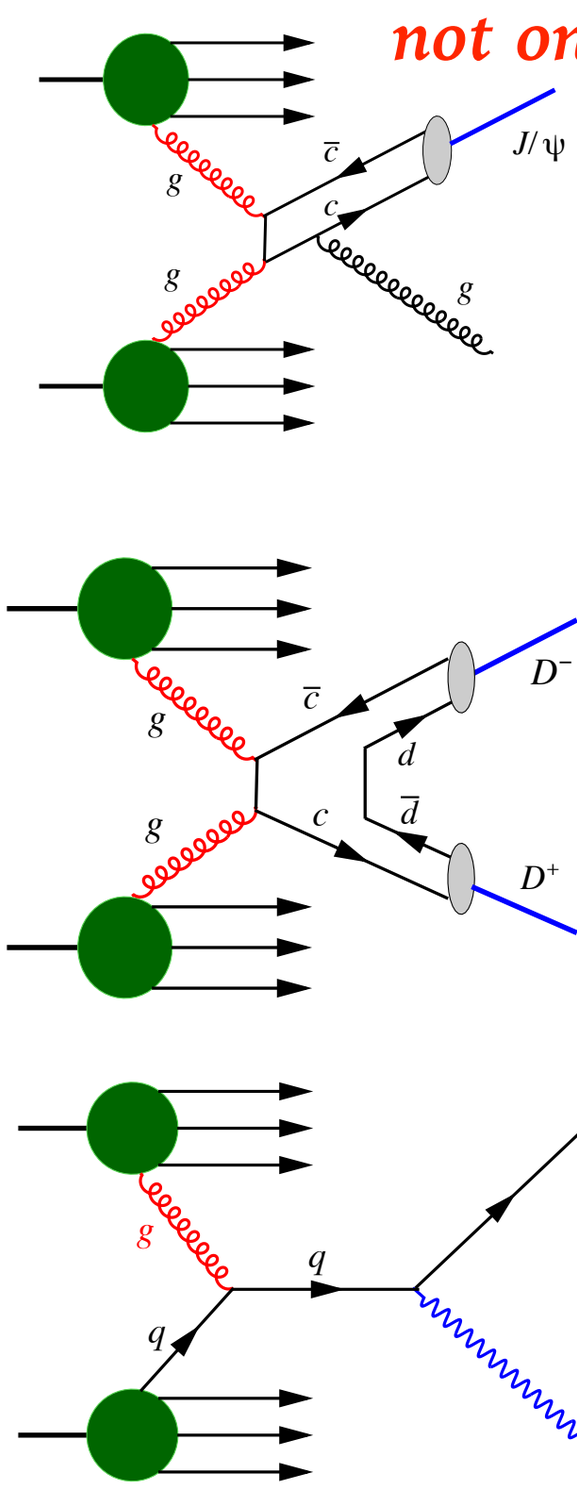


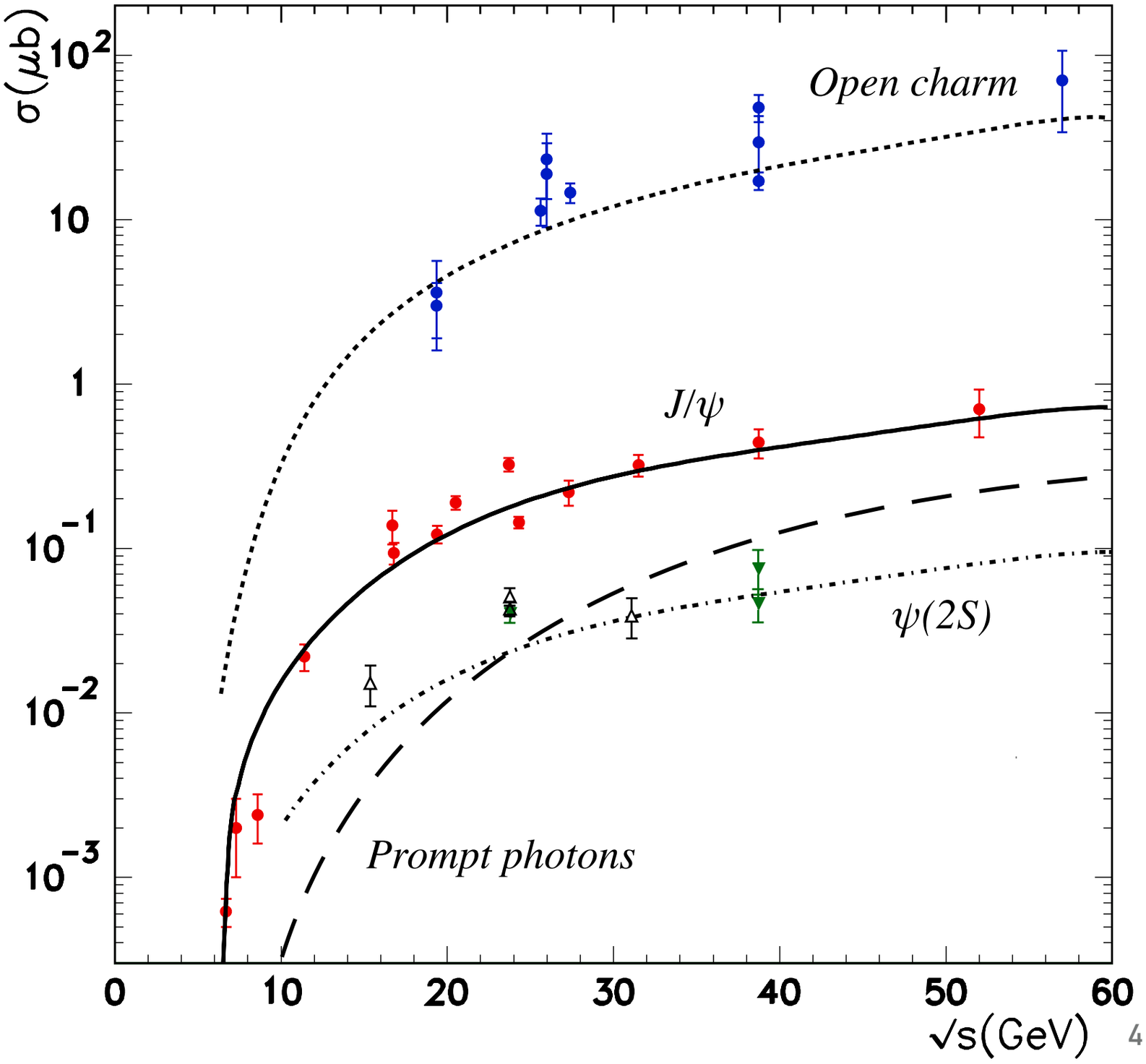
Experimental facility	SPD @NICA	RHIC	EIC	AFTER @LHC	LHCspin
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^{\uparrow}$-$p^{\uparrow}$ $d^{\uparrow}$-$d^{\uparrow}$ $p^{\uparrow}$-d, p-$d^{\uparrow}$	$p^{\uparrow}$-$p^{\uparrow}$	$e^{\uparrow}$-$p^{\uparrow}$, $d^{\uparrow}$, ^{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 we are unique

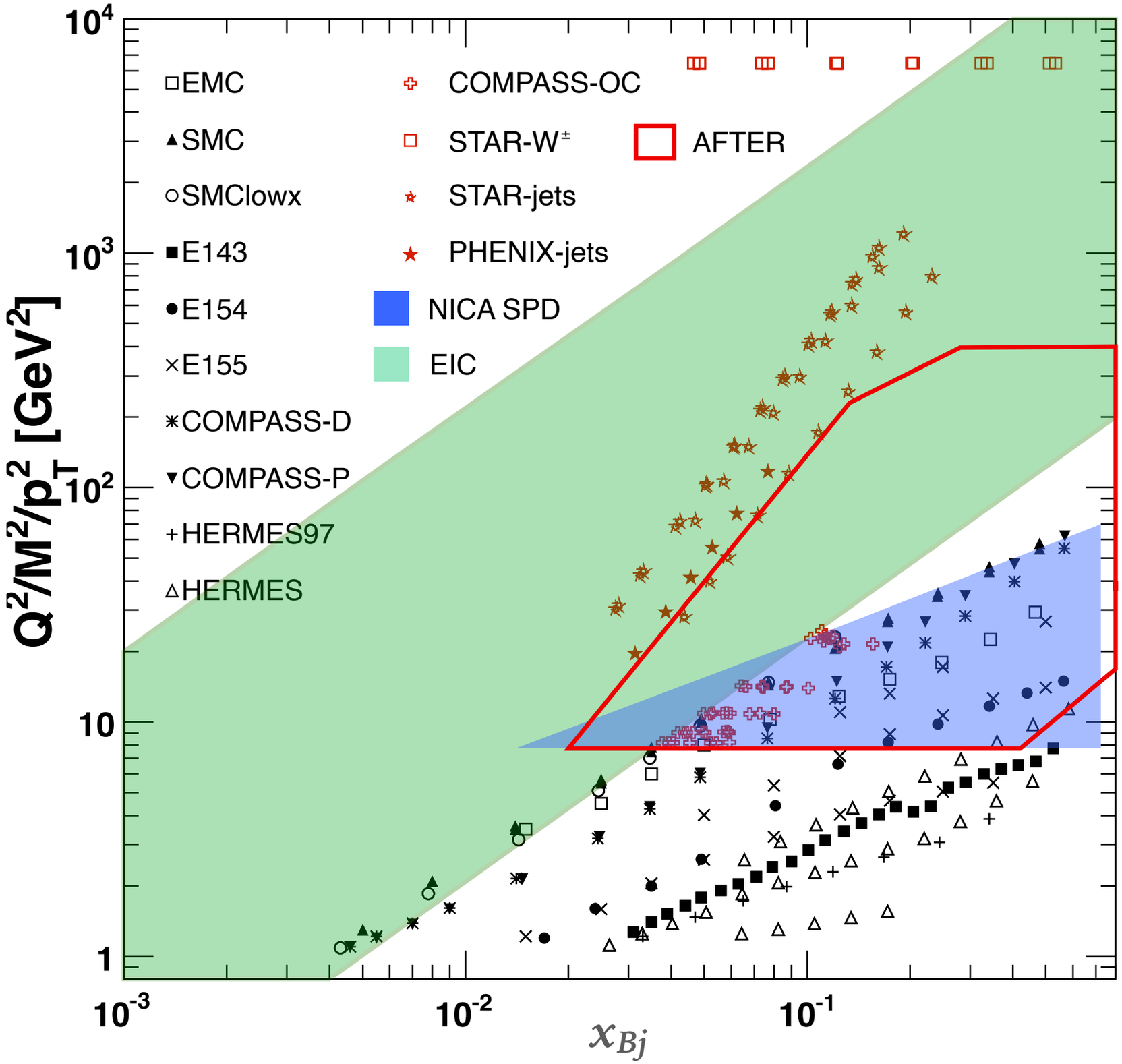
GLUON PROBES AT SPD

not only J/ψ!





MAIN PLAYERS IN POLARIZED GLUON PHYSICS



SPD can cover this range for polarised gluon studies in p↑-p↑ interactions!

open charm

charmonia

high-p_T prompt photons

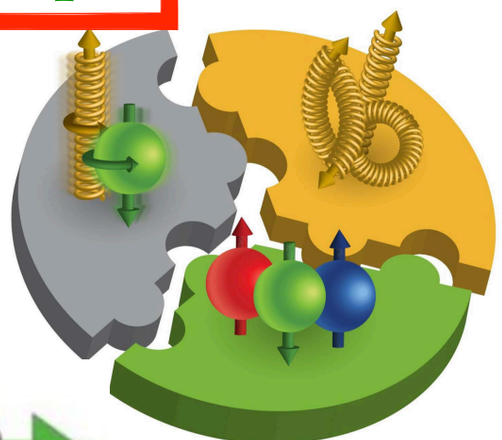
PARTONIC STRUCTURE OF PROTON AND DEUTERON

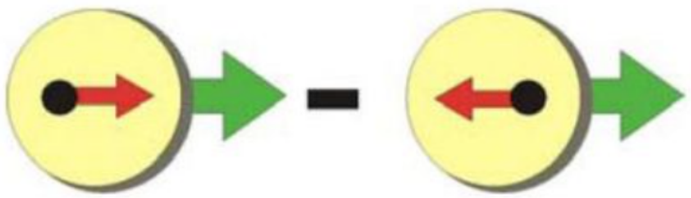
$\sigma(x_F,p_T)$ $A_{LL}(x_F,p_T)$

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

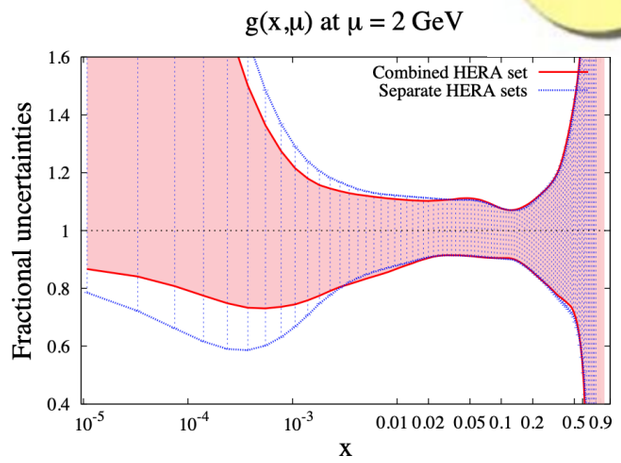
Spin crisis:

Gluon helicity

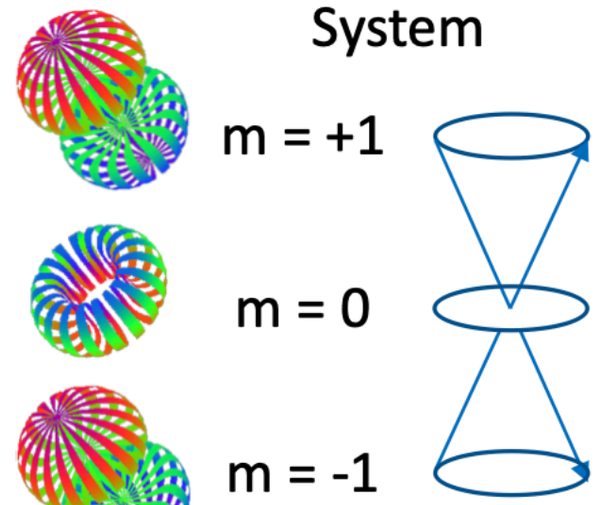




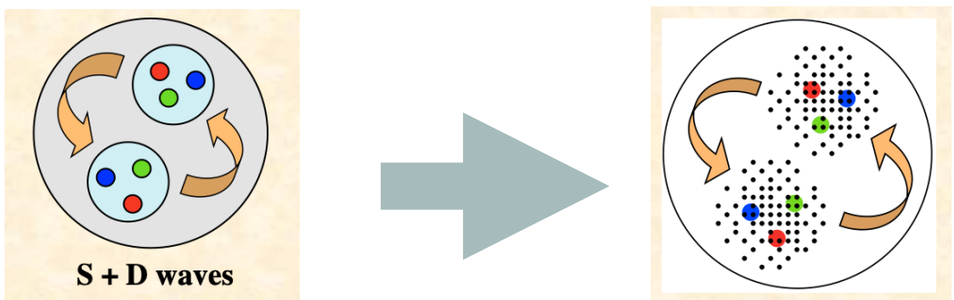
Unpolarized gluons in proton and deuteron at high x:



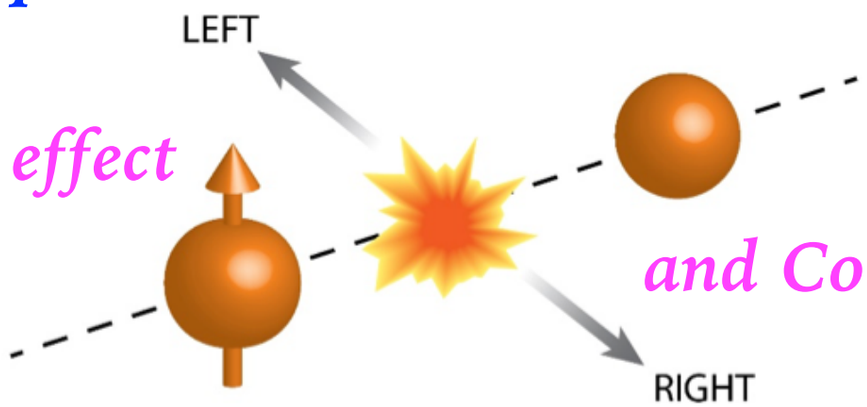
Tensor structure of deuteron:



Nonbaryonic content of deuteron:



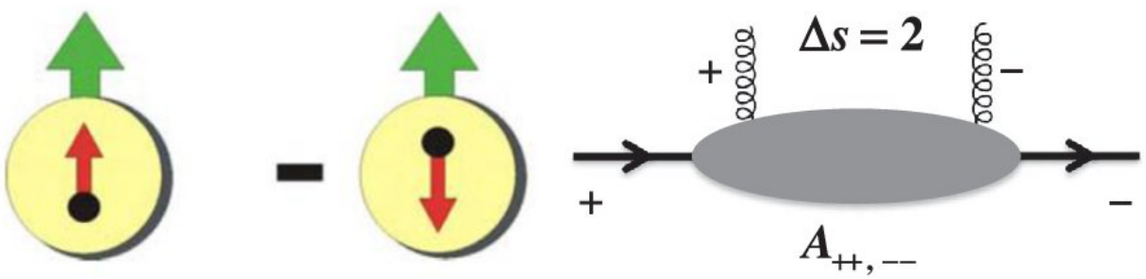
Gluon and quark TMD PDFs:



Sivers effect

and Collins effect

Gluon transversity



- *spin-dependent fragmentation functions*

Основные направления активности в 2019-2022

- Пересмотр физической программы
- R&D по подсистемам установки SPD
- Подготовка концептуального проекта эксперимента (SPD CDR)
- Оборудование тестовой зоны SPD
- Создание международной коллаборации
- Подготовка технического проекта эксперимента (SPD TDR)

Пересмотр физической программы эксперимента

Prepared for Physics of Elementary Particles and Atomic Nuclei. Theory

Progress in Particle and Nuclear Physics
Volume 119, July 2021, 103858

Review

On the physics potential to study the gluon content of proton and deuteron at NICA SPD

A. Arbuzov [a], A. Bacchetta [b, c], M. Butenschoen [d], F.G. Celiberto [b, c, e, f], U. D'Alesio [g, h], M. Deka [a], I. Denisenko [a], M.G. Echevarria [i], A. Efremov [a], N.Ya. Ivanov [a, j], A. Guskov [a, k] ✉, A. Karpishkov [l, a], Ya. Klopot [a, m], B.A. Kniehl [d], A. Kotzinian [j, o], S. Kumano [p], J.P. Lansberg [q], Keh-Fei Liu [r] ... O. Teryaev [a]

Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams

V.V. Abramov[1], *A. Aleshko*[2], *V.A. Baskov*[3], *E. Boos*[2], *V. Bunichev*[2], *O.D. Dalkarov*[3], *R. El-Kholy*[4], *A. Galoyan*[5], *A.V. Guskov*[6], *V.T. Kim*[7,8], *E. Kokoulina*[5,9], *I.A. Koop*[10,11,12], *B.F. Kostenko*[13], *A.D. Kovalenko*[5], *V.P. Ladygin*[5], *A. B. Larionov*[14,15], *A.I. L'vov*[3], *A.I. Milstein*[10,11], *V.A. Nikitin*[5], *N. N. Nikolaev*[16,26], *A. S. Popov*[10], *V.V. Polyanskiy*[3], *J.-M. Richard*[17], *S. G. Salnikov*[10], *A.A. Shavrin*[18], *P.Yu. Shatunov*[10,11], *Yu.M. Shatunov*[10,11], *O.V. Selyugin*[14], *M. Strikman*[19], *E. Tomasi-Gustafsson*[20], *V.V. Uzhinsky*[13], *Yu.N. Uzikov*[6,21,22,*], *Qian Wang*[23], *Qiang Zhao*[24,25], *A.V. Zelenov*[7]

[1] NRC "Kurchatov Institute" - IHEP, Protvino 142281, Moscow region, Russia

[2] Skobeltsyn Institute of Nuclear Physics, MSU, Moscow, 119991 Russia

[3] P.N. Lebedev Physical Institute,Leninsky prospect 53, 119991 Moscow, Russia

SPD Conceptual Design Report

CDR was presented on the meeting of the JINR Program Advisory Committee for particle physics in Jan, 2021

JOINT INSTITUTE FOR NUCLEAR RESEARCH

February 3, 2021

arXiv:2102.00442

Conceptual design of the Spin Physics Detector

Version 1.0

The SPD proto-collaboration*

International Detector Advisory committee was formed to review the CDR

Andrea Bressan, INFN/ University of Trieste
chair

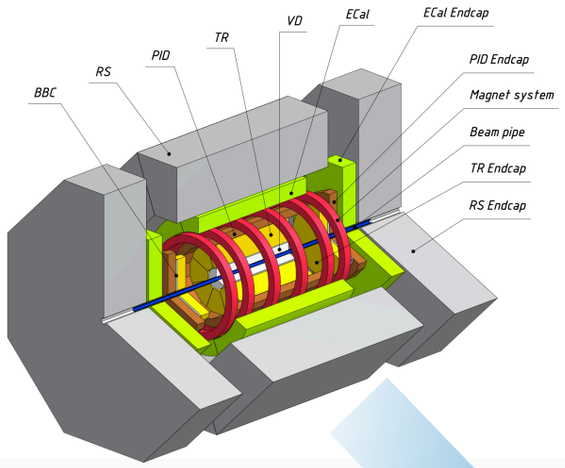
Peter Hristov, CERN

Pasquale di Nezza, INFN, Frascatti

SPD DAC presented the report on the CDR at the PAC session in Jan, 2022

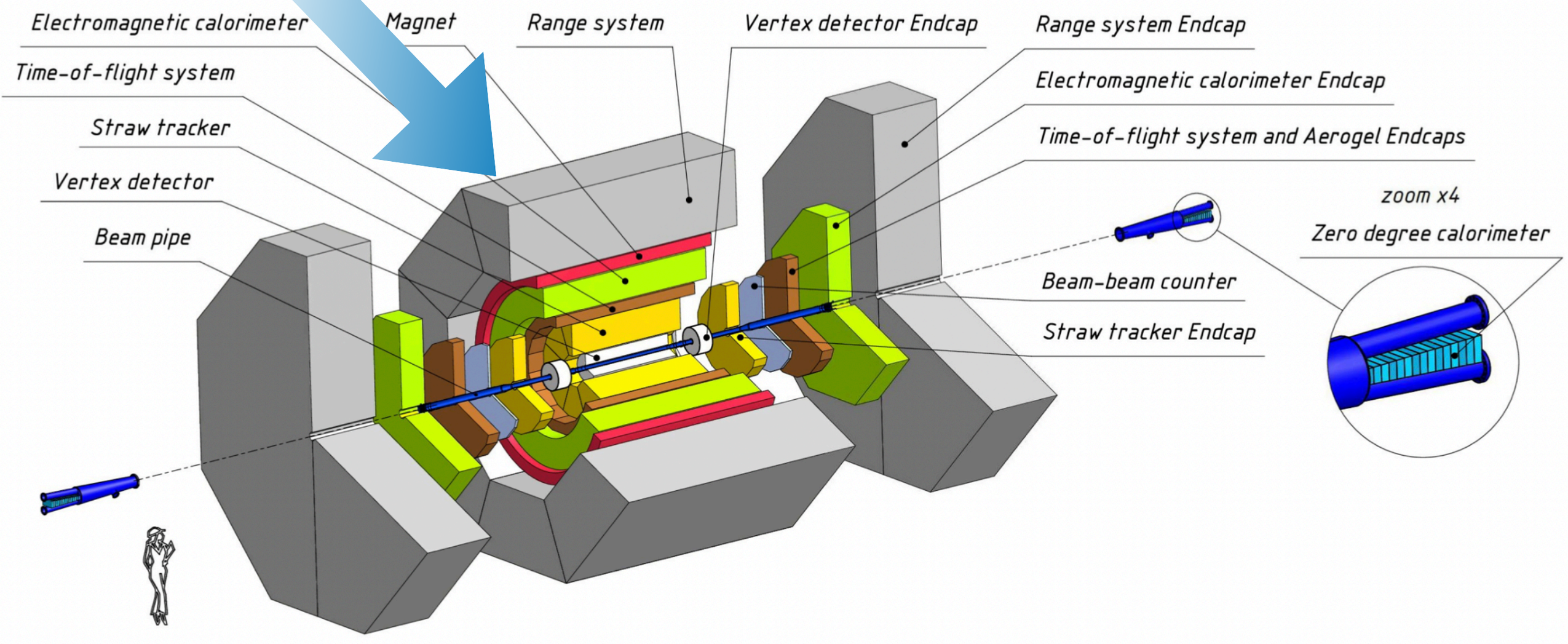
CDR was approved by the JINR Program Advisory Committee for particle physics in Jan, 2022

SPD Technical Design Report

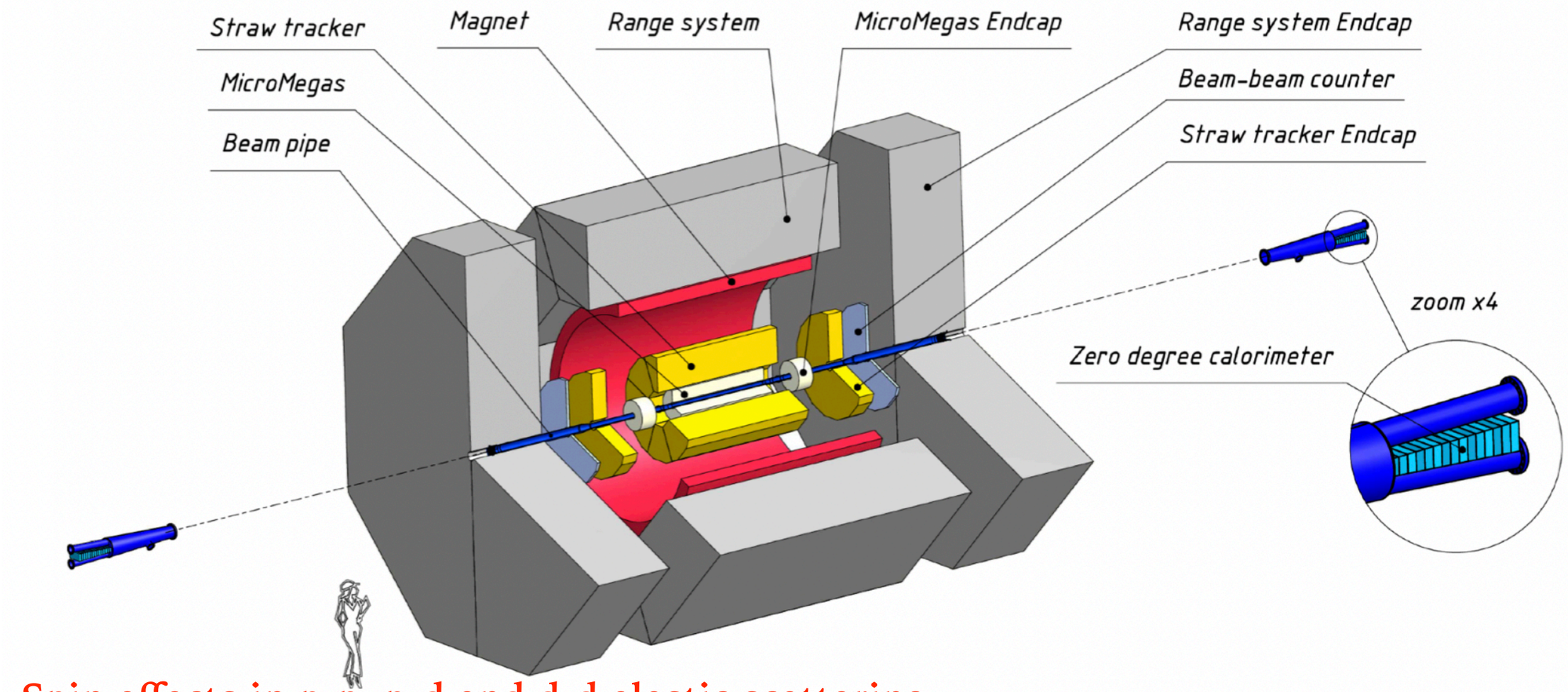


Основные изменения по сравнению с CDR

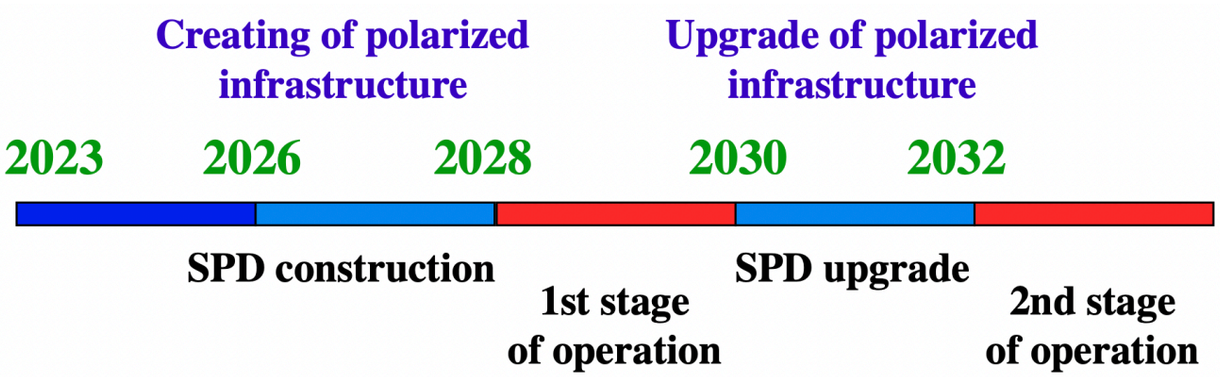
- Новый сверхпроводящий соленоид
- Аэрогель только в энд-капах
- Закрыт вариант вершинного детектора DSSD+MAPS
- **Первая фаза**



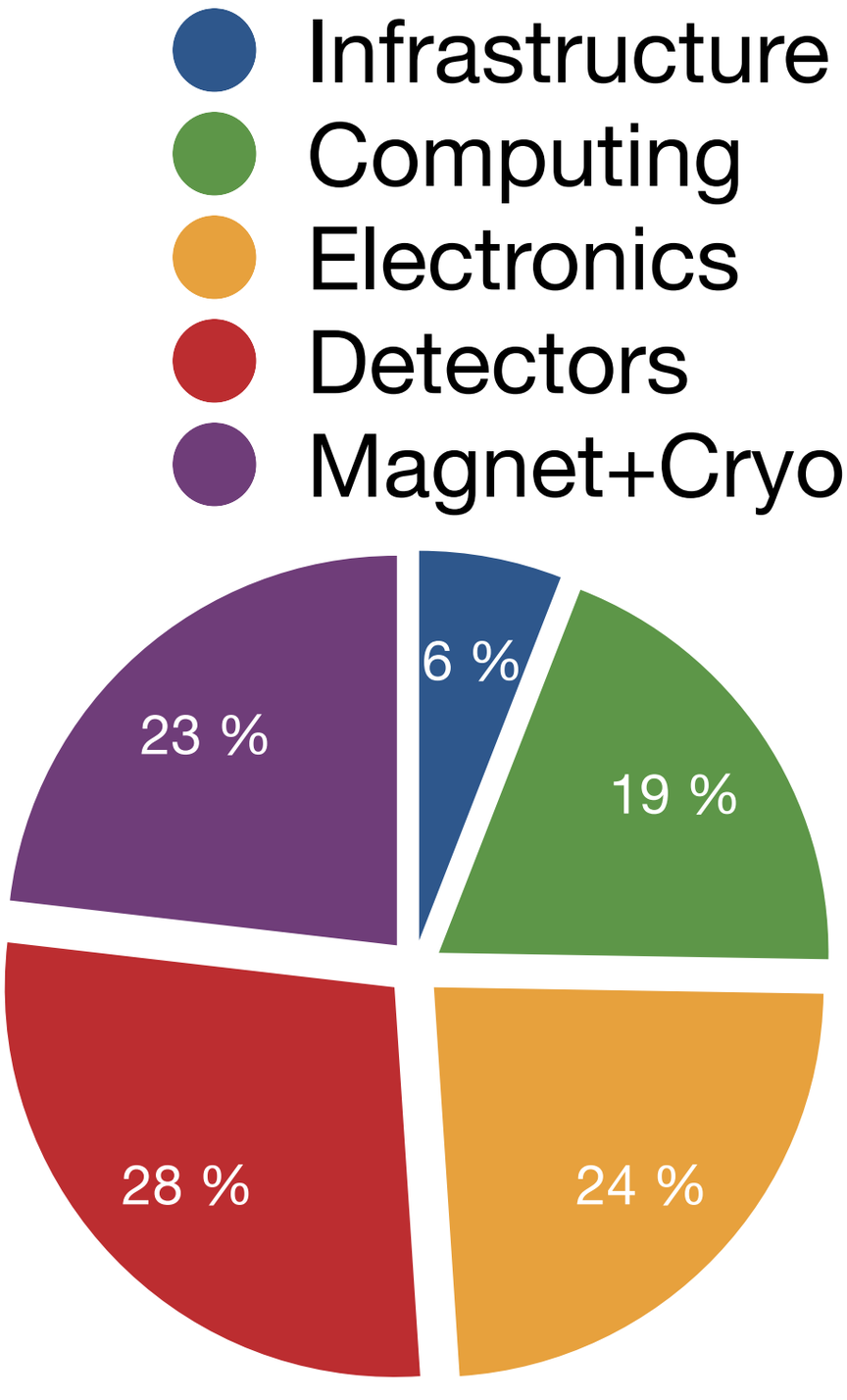
SPD Technical Design Report: Phase-1



- Spin effects in p-p, p-d and d-d elastic scattering
- Spin effects in hyperons production
- Multiquark correlations
- Dibaryon resonances
- Physics of light and intermediate nuclei collision
- Exclusive reactions
- Hypernucei
- Open charm and charmonia near threshold
- Auxiliary measurements for astrophysics
- …



Cost estimate



Subsystem	Option	Phase	Cost, M$
SPD setup	Vertex detector:		
	– DSSD	II	8.0+6.5 (FEE)
	–MAPS	II	15
	–Micromegas	I	0.8
	Straw tracker	I+II	2.7
	PID system:		
	– TOF	II	2.9
	– Aerogel PID system	II	2.4
	ECAL		
	–Phantom	I	0.4
		I+II	9.4
	Range system	I+II	15.7
	ZDC	I+II	0.6
	BBC	I+II	0.2+0.2
	Magnetic system		
	Novosiborsk option	I+II	8.2
	JINR option	I+II	
	& cryogenic infrastructure	I+II	
	Novosiborsk option	I+II	3.4
	JINR option	I+II	3.1
	Beam pipe		
	– Al	I	0.1
	– Be	II	0.4
General infrastructure		I	1.2
		I+II	1.7
Slow control system		I	0.5
		I+II	0.8
Data acquisition system		I	0.8
		I+II	1.9
Computing		I	4
		I+II	12
TOTAL COST	stage I		38.8
	stage I+II		78.4

SPD international collaboration

31 institutes from 14 countries, ~300 members

4.6.2021 -
SPD Collaboration
Board утвердил
конституцию

Proto-collaboration meeting , June, 2019, Dubna

SPD collaboration meeting, June 2021, remote
SPD collaboration meeting, November 2021, remote

MoU was agreed by CB for signing on 18.2.22

Органы коллаборации SPD

Spokespersons

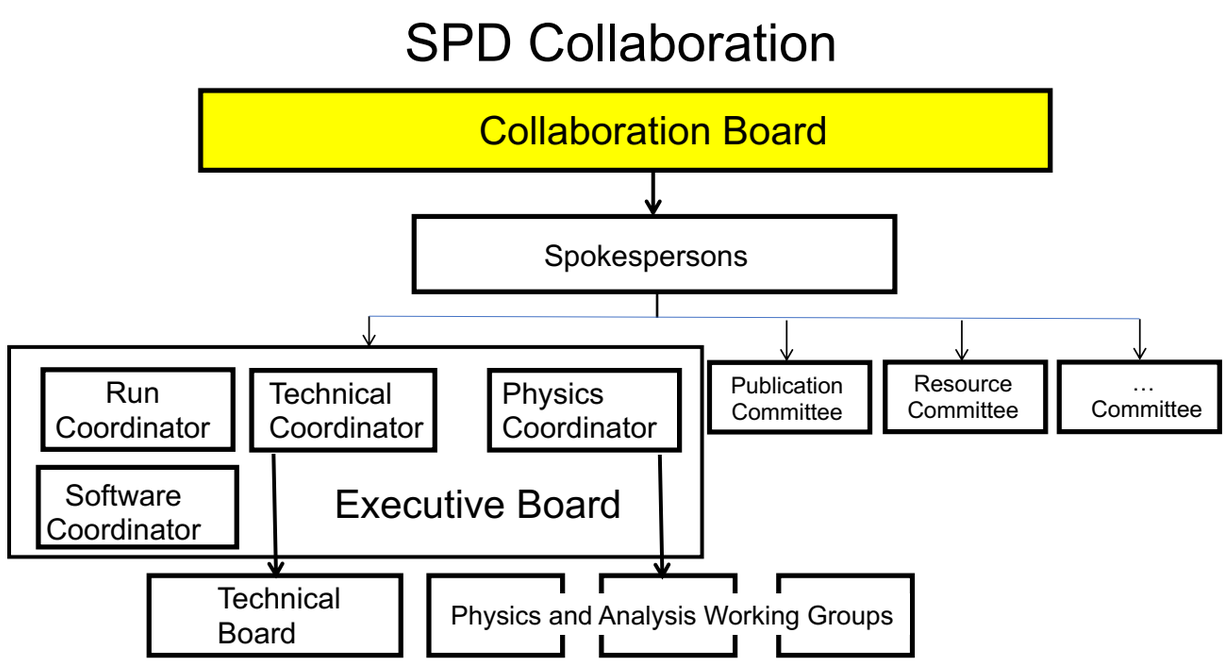
A. Guskov	**JINR**
V. Kim	**Gatchina, PNPI**

Executive Board

A. Guskov	JINR	Spokesperson
V. Kim	PNPI	Spokesperson
A. Korzenev	JINR	Technical coordinator
V. Ladygin	JINR	Representative of the host lab.
E. Tomasi	Saclay, France*	CB-chair
A. Zhemchugov	JINR	Software coordinator
I. Denisenko	JINR	Physics coordinator
V. Anosov	JINR	
A. Baldin	JINR	
O. Dalkarov	Lebedev Institute	
A. Kovalenko	JINR	
A. Kulikov	JINR	
D. Panzieri	Turino Univ./ INFN, Italy	
Y. Wang	Tsinghua Univ., China	

Publication Committee

O. Teryaev	JINR
A. Korzenev	JINR
V. Ladygin	JINR
E. Tomasi	Saclay, France
V. Kim	Gatchina, PNPI
P. Jones	iThemba Labs, SA
A. Guskov	JINR
A. Kulikov	JINR



Collaboration Board

E. Tomasi	Saclay, France
+30 group leaders	

Technical Board

L. Afanasiev	JINR	DAQ
G. Alexeev	JINR	Range System
I. Alexeev	ITEP, Russia	ZDC
M. Alexeev	Turino Univ., Italy	
V. Anosov	JINR	integration
A. Baldin	JINR	test zone
Y. Bedfer	Saclay, France	
T. Enik	JINR	Straw tracker
O. Gavrishchuk	JINR	ECal
A. Guskov	JINR	ex officio
A. Korzenev	JINR	technical coordinator
V. Kim	PNPI	ex officio
V. Ladygin	JINR	BBC and polarimetry
A. Livanov	JINR	Experimental hall coordinator
X. Li	CIAE, China	
Y. Wang	Tsinghua Univ., China	
N. Zamyatin	JINR	Vertex Detector
	+ a few permanent guests	

	VD	Straw	TOF	Aerog	ECAL	RS	Magnet	BBC	ZDC	MM	DAQ+FFE	SlowC	Comp/soft	MC&phys
AANL, Erevan				■	■									■
IAP NAS, Minsk														■
INP BSU, Minsk		■												
GTSU, Gomel														■
Chilie								■			■			
Tsinghua Univ, Beijing			■		■									
CIAE, Beijing		■			■					■				
InsTec, Havana														■
Charles Univ., Prague	■													
CTU, Prague	■													
Cairo Univ, Cairo													■	■
Turin Univ, & INFN, Turin	■										■			
WUT, Warsaw					■									
JINR	■	■			■	■	■	■	■	■	■	■	■	■
Lebedev Inst, Moscow			■										■	■
PNPI, Gatchina		■											■	■
NPI MSU, Moscow	■					■					■	■		■
ITEP, Moscow								■	■					■
INR, Troitsk											■			
IHEP, Protvino	■		■											
Samara Univ., Samara													■	■
SPbPTU, St. Petersburg											■			■
SPbSU, St. Petersburg	■							■						
TSU, Tomsk														■
BSU, Belgorod								■	■			■		
iThemba LABS, SA											■	■	■	
IoP, Belgrade Univ., Belgrade													■	■
KhNU, Kharkiv					■								■	
ISMA, Kharkiv					■								■	
CEA Saclay										■				
BINP, Novosibirsk							■							

Working plan

- 2022: R&D for the main components of the SPD including infrastructure and computing. Tests of the detectors, electronics, DAQ and infrastructure with the Nuclotron beam at the SPD test zone. Presentation of the preliminary version of the Technical Project. Discussion of the Technical Project with the SPD Detector Advisory Committee.
- **2023: R&D for the main components of the SPD. Tests of the detectors, electronics, DAQ and infrastructure with the Nuclotron beam at the SPD test zone. Finalization of the technical project for the initial configuration of the SPD setup. Preparation to the production of the main SPD setup components (magnetic system, straw tracker, range system etc.) and corresponding infrastructure. Preparation of the SPD experimental hall infrastructure;**
- **2024-2025: Production of the SPD setup components for the first phase of the experiment: range system, magnet, straw tracker, micromegas detector, ZDC, and BBC. Work on DAQ, slow control and distributed computing infrastructure.**
  Continuation of the R&D for the detectors of the second phase: ECAL, ToF, aerogel detector, and silicon vertex detector.
- 2026-2027: Installation and commissioning of the magnetic system. Construction of the first-phase SPD configuration.
- 2028: Beginning of the SPD operation in its basic configuration.

Working plan

	2022	2023	2024	2025	2026	2027	2028
	SPD Technical Design Report						
	Magnet						
Technical project							
Production							
Commissioning at JINR							
	1-stage detectors*						
R&D							
Production							
Commissioning							
Installation							
	2-stage detectors**						
R&D							
Production							
	Data taking						
	Development of NICA polarized infrastructure						

* - Micromegas, Straw, Range System, BBC, ZDC

** - ECAL, ToF, Silicon Vertex, Aerogel

Manpower

	Человек	FTE	FTE, %	Человек с FTE≥0.7
Всего	**148**	**78.4**	**100**	**32**
Моложе 35 лет	38	22.3	28 %	10
Детекторы		36.8	47 %	
Моделирование		16.1	21 %	
Теория/физика		8	10 %	
Компьютинг		7.5	10 %	
Электроника & DAQ		5.5	7 %	
Инженеры/конструкторы		4.5	6 %	
ЛФВЭ		41.3	53 %	
ЛЯП		31.2	40 %	
ЛИТ		3.4	4 %	
ЛТФ		2.5	3 %	

Main hardware groups (JINR)

Group leaders	Lab	System
Afanasyev L.	DLNP	DAQ
Alexeev G.	DLNP	Range system
Baldin A. + Ladygin V.	VBLHEP	BBC
Gavrischuk O.	VBLHEP	ECAL
Gongadze A.	DLNP	Micromegas
Enik T. + Kekelidze G.	VBLHEP	Straw
D. Nikiforov	VBLHEP	Cryogenics
Zamyatin N.	VBLHEP	Silicon vertex detector

Форма 26

Expenditures, resources, financing sources			Costs (k$) Resource requirements	Proposals of the Laboratory on the distribution of finances and resources		
				1st year	2nd year	3rd year
Expenditures, $		Main units of equipment, work towards its upgrade, adjustment etc.	6750	450	3700	2600
		Construction/repair of premises	800	100	500	200
		Materials	32650	400	17 300	14 700
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; Laboratory experimental facilities division; – accelerator; – computer. Operating costs.	45 MCPU*h Nuclotron, h 900	10 300	15 300	20 300
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	41 350	1350	22 000	18 000
	External resources	Contributions by collaborators. Grants. Contributions by sponsors. Contracts. Other financial resources, etc.	250	50	100	100

Форма 29

Expenditure items	Full cost	1st year	2nd year	3rd year…
Direct expenses for the Project				
1. Nuclotron, h	900	300	300	300
2. Computers (M CPU*h)	45	10	15	20
3. Computer connection, k$				
4. Design bureau, norm*h	45000	10000	15000	20000
5. Experimental Workshop, norm*h				
6. Materials	32 650 k$	450 k$	17 400k$	14 800k$
7. Equipment	6 750 k$	450 k$	3 700 k$	2 600 k$
8. Construction/repair of premises	800 k$	100 k$	500 k$	200 k$
9. Payments for agreement-based research	920 k$	240 k$	340 k$	340 k$
10. Travel allowance, including: a) non-rouble zone countries b) rouble zone countries c) protocol-based	480 k$ 360 k$ 90 k$ 30 k$	160 k$ 120 k$ 30 k$ 10 k$	160 k$ 120 k$ 30 k$ 10 k$	160 k$ 120 k$ 30 k$ 10 k$
Total direct expenses	41 600$	1 400$	22100k$	18100k$