QUARKS-2026

XXIII INTERNATIONAL SEMINAR
ON HIGH-ENERGY PHYSICS

Petrozavodsk , Russia
18-23 May 2026

Progress in Physics at NICA

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Petersburg Nuclear Physics Institute
NRC “Kurchatov Institute”, Gatchina, Russia

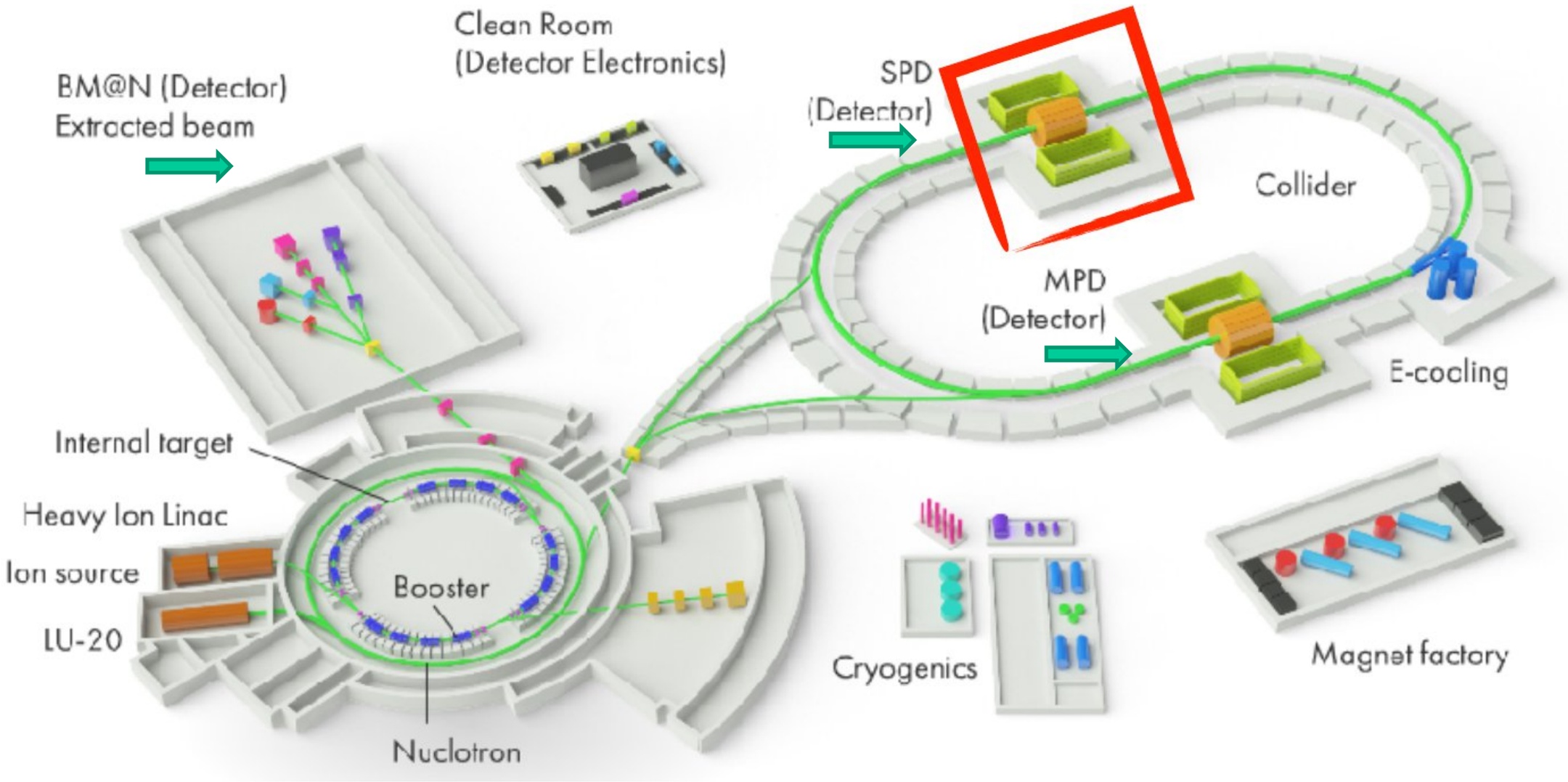
«QUARKS-2026»
Petrozavodsk, May 18-23 2026

Physics Highlights at NICA
NICA: Nuclotron-based Ion Collider fAcility

- **BM@N: Baryonic Matter at Nuclotron**
- **MPD: Multi-Purpose Detector**
- **SPD: Spin Physics Detector**

BM@N, MPD, SPD at NICA Collider (JINR, Dubna)

NICA:
Nuclotron-based Ion Collider fAcility



Why Strong Interactions Physics?

Search for New Physics:

- Search for New Particles and Interactions beyond the Standard Model

- Search for New Dynamics within the Standard Model

BM@N, MPD, SPD at NICA Collider (JINR, Dubna)

NICA: Nuclotron-based Ion Collider fAcility

BM@N: Baryonic Matter at Nuclotron

Extracted Nuclotron beam up to 6A GeV

Strange Hadrons: Nuclear Matter Equation-of State (EoS)

MPD: Multi-Purpose Detector

NICA beams up to 6A+6A GeV

Very Hot Dense Baryonic Matter

t~10^{-8}s after Big Bang

Phase Transitions, Nucleosynthesis

SPD: Spin Physics Detector

Intensive NICA pp- and dd- beams 8-27 GeV/NN

Polarized and non-Polarized beams

3D Quark- and Gluon- distributions at large x

Proton and deuteron spin structures

Ariadna: Applied Physics

Material science and technologies at extracted beams

Baryonic Matter at NICA (JINR, Dubna)

NICA:
Nuclotron-based Ion Collider fAcility

Dense Baryon Matter Properties

BM@N: Baryonic Matter at Nuclotron (Fixed Target)
Extracted Nuclotron beam up to 4-6A
Strange Hadrons: Nuclear Matter Equation-of State (EoS)

MPD: Multi-Purpose Detector
NICA beams up to 6A+6A
Very Dense Baryonic Matter
Phase Transitions t~10^{-9}s after Big Bang

Dense Baryon Matter Studies Prior at NICA

BNL (Brookhaven, NY):

A+A beams up to 100A+100A GeV

STAR, PHENIX

LHC (CERN):

A+A beams up to 2760A+2760A GeV

ALICE, ATLAS, CMS

High Temperatures, but Not High Densities! <- Asympt. Freedom

NICA Collider: Optimal Temperatures and High Densities!

MPD: Multi-Purpose Detector

NICA beams up to 6A+6A GeV

Very Dense Baryonic Matter

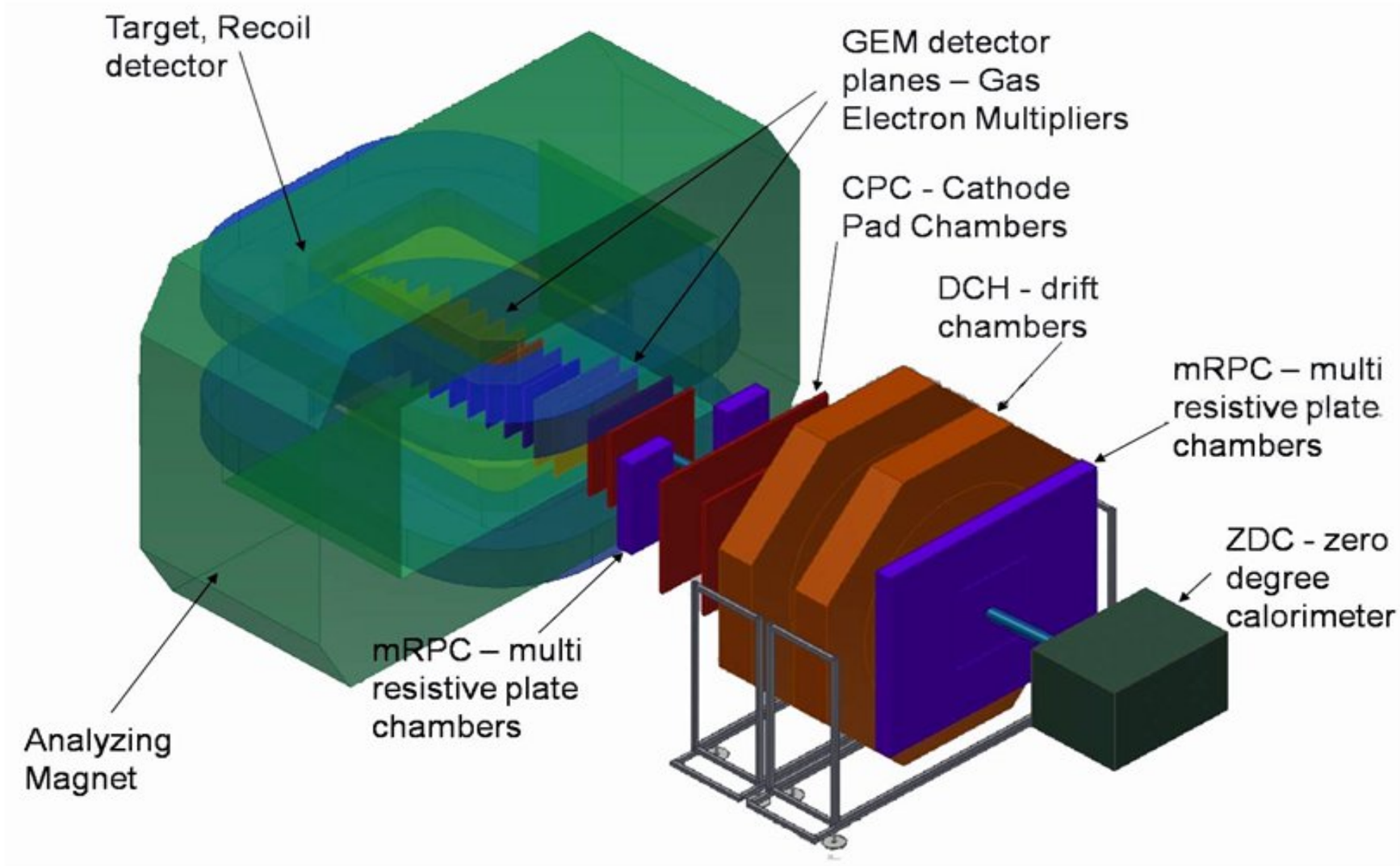
Phase Transition

Neutron Star Center Conditions

Nucleosynthesis t~10^{-8}s after Big Bang

BM@N at NICA fixed target (JINR, Dubna)

BM@N NICA:
Baryonic Matter at NICA



BM@N at NICA (JINR, Dubna)

BM@N NICA:
Baryonic Matter at NICA

The 1st Stage of BM@N: in Operation since 2015

BM@N Collaboration:
Spokesperson: Richard Lednicky (JINR)
Ex-SP: Mikhail Kapishin (JINR)

Participants > 200
Organizations: 14
Countries: 13

Hyperon production in AA-collisions:
Nuclear Equation of State (EoS)

BM@N NICA: Current Data Analyses and Plans

Topics of current physics analyses:

- analysis of production of Λ, Ξ- hyperons, K^0_S , K±, π±, φ mesons, light nuclear fragments in Xe+CsI interactions;
- collective flow of protons, deuterons, Λ
- femtoscopy of protons, deuterons, Λ
- light hyper-nuclei $_{\Lambda}H^3$, $_{\Lambda}H^4$

Physics run in the Xe beam in 2026 + Kr beam

→ beam energy scan: 3.0, 2.2, 1.6 AGeV
→ same central tracker configuration based on silicon micro-strip and GEM
→ additional 1st vertex plane of silicon micro-strip detectors
→ ToF-400 acceptance extended by 1.5
→ trigger rate up to 20 kHz (DAQ and pile-up limit)

Preparations for a physics run with the Bi beam

- Further development of the central tracker is foreseen: installation of additional stations of silicon micro-strip detectors
- It is planned to put into operation a 2-coordinate (X/Y) neutron detector of high granularity to measure neutron yield and collective flow
- Further extension of the ToF-400 acceptance to low momenta

Experiments in a polarized deuteron beam in energy range 3.0 – 4.5 AGeV

- Reactions: d ↑ + p (LH) → Λ (VM) + X

Look to more distant future:

- R&D activity to develop and implement MAPS detectors to BM@N tracking

MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA

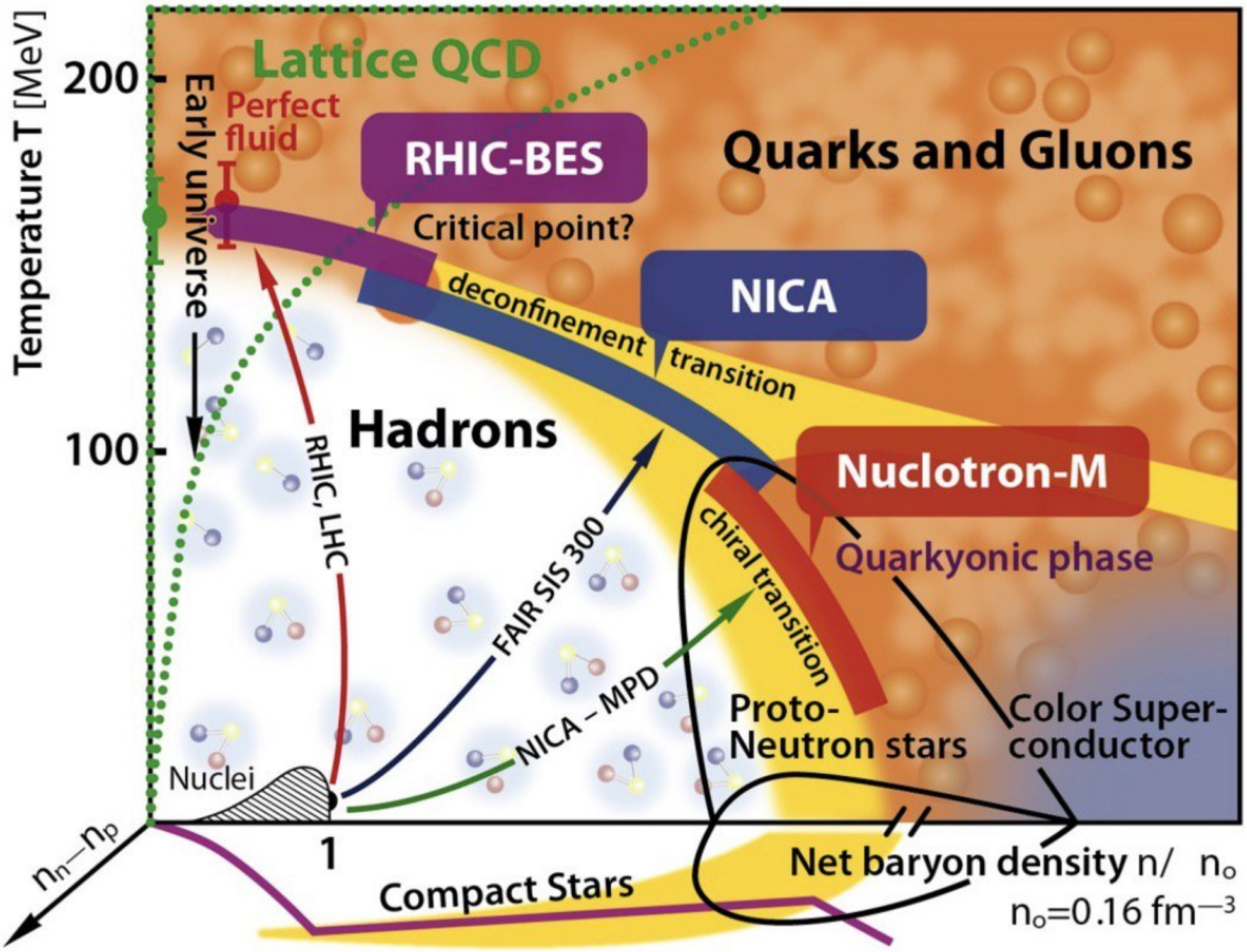
The Multi-Purpose Detector (MPD)
- **the main heavy-ion experiment at NICA Collider**
- **the energy range from from 4 to 11 GeV per NN**

The main MPD goal:
to examine the region of the QCD phase diagram with a high baryon chemical potential, where a first-order phase transition and the onset of the critical endpoint are predicted to occur.

Preparations for data collection in the MPD: Fall of 2026.

MPD physics program:
- **hadron spectra and hypernucleus production,**
- **collective flow, correlations and fluctuations,**
- **hyperon global polarization,**
- **electromagnetic probes,**
- **open charm production**

MPD at NICA Collider (JINR, Dubna)



MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA

The main MPD Physics Tasks:

First-Order vs. Cross-Over: At high temperatures but low baryonic density, the phase transition is a smooth "cross-over". However, at NICA's high baryonic densities, theoretical models predict a transition to a first-order phase transition.

The Critical End-Point (CEP): NICA will attempt to locate the hypothetical critical end-point where the first-order transition line ends and becomes a smooth transition.

Fluctuations and Probes: NICA's multi-detector experiments look for anomalies such as event-by-event fluctuations in particle yields, higher-order cumulants of conserved charges (like baryon numbers), collective flow of emitted particles, and enhanced production of multi-strange hyperons.

MPD NICA:
Multi-Purpose Detector at NICA

MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA

The 1st Stage of MPD: Under Commissioning
Beam-ready at Fall 2026

MPD Collaboration:
Acting Spokesperson: Victor G. Riabov (JINR & NRC KI - PNPI)
Deputy SPs: Zebo Tang (CPPT, Hefei)
Arkadiy Taranenko (MEPhI)

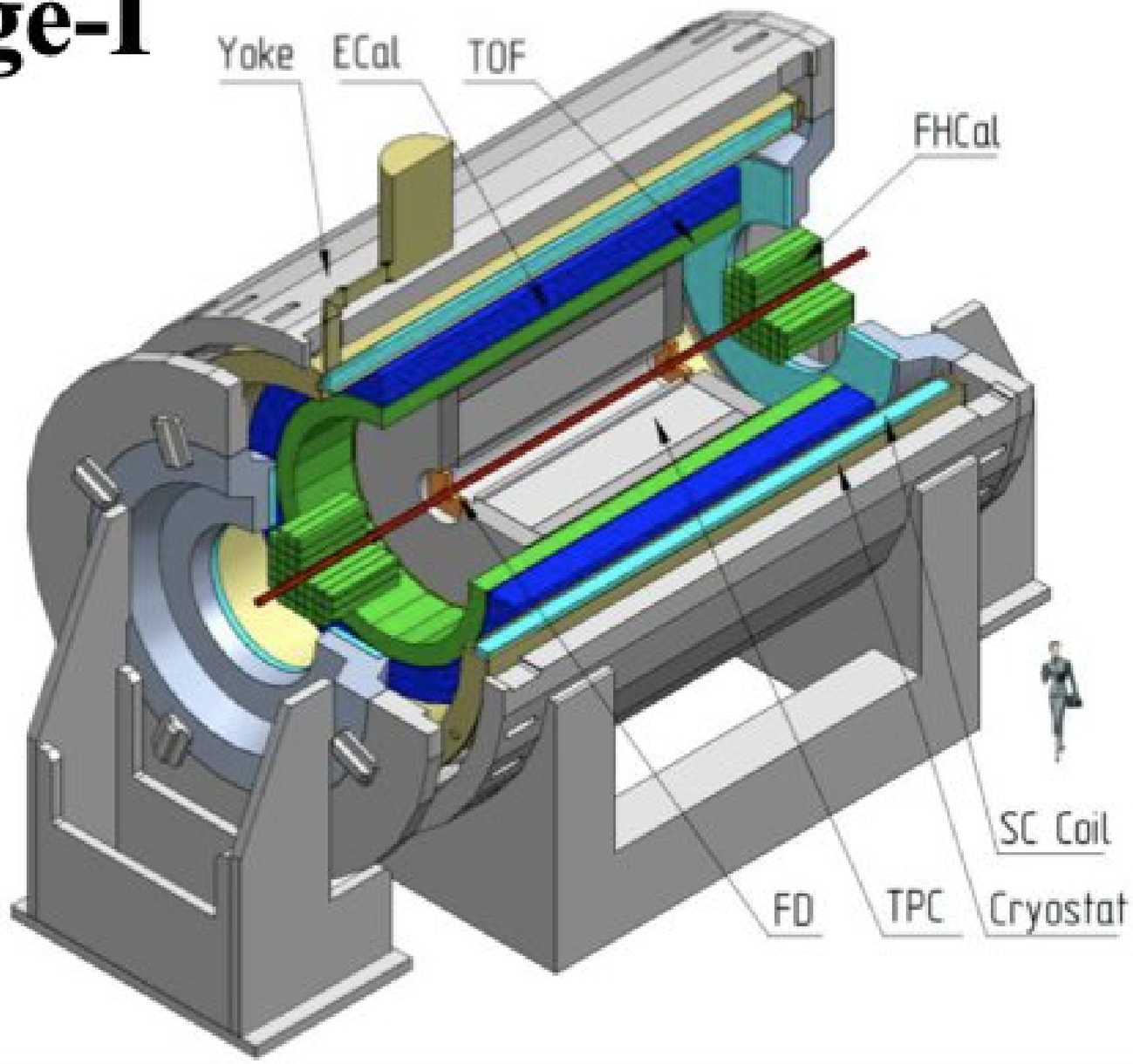
Participants > 500
Organizations = 39
Countries = 12

MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA

NICA MPD

Stage-I

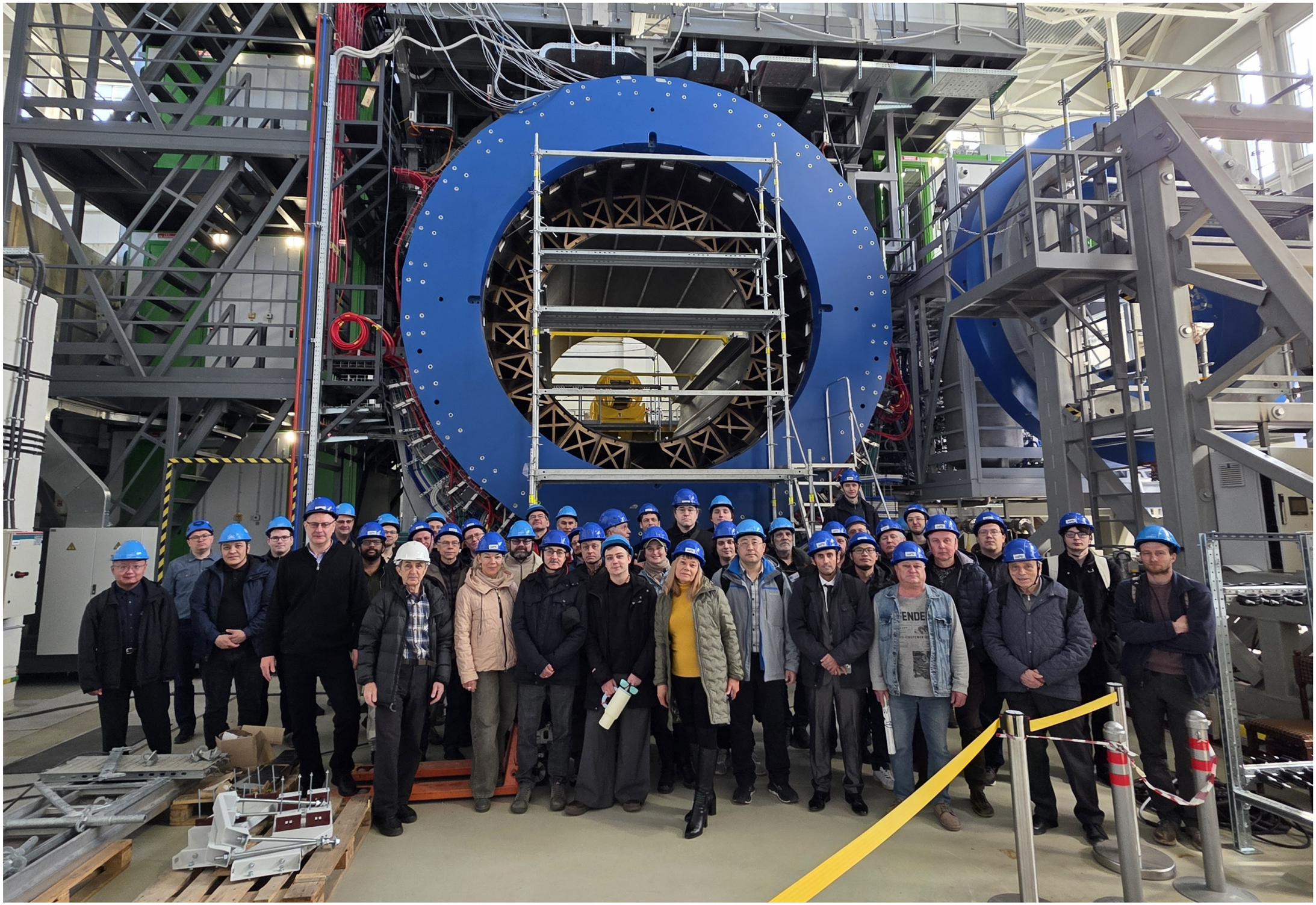


TPC: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.6$; **TOF, EMC**: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.4$

FFD: $|\Delta\varphi| < 2\pi$, $2.9 < |\eta| < 3.3$; **FHCAL**: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA



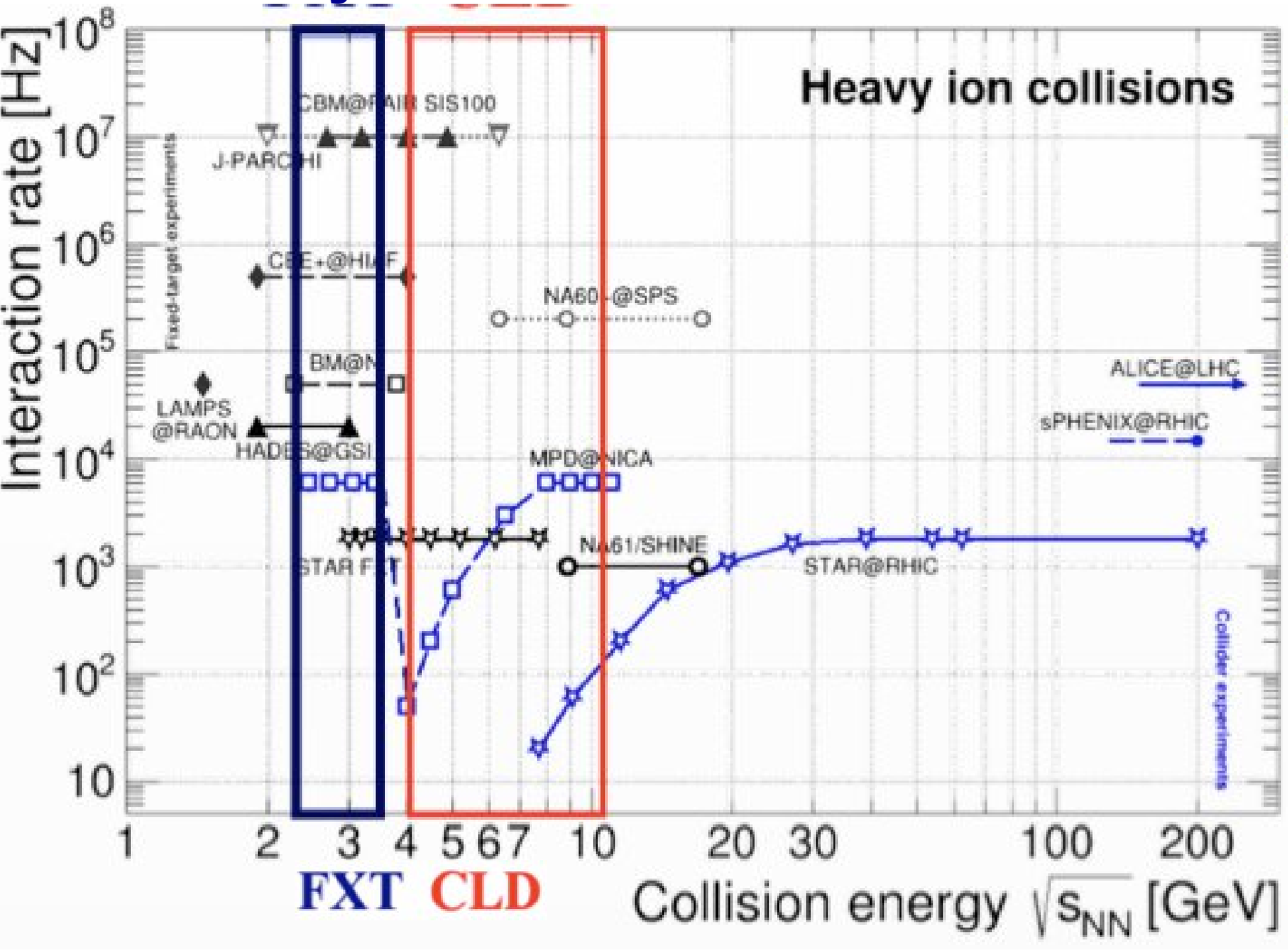
MPD at NICA Collider (JINR, Dubna)

MPD-FXT (fixed target mode)

MPD-CLD (collider mode)

Hadron Spectra:

- **Collision Energy scan**
- **System Size scan**



competitors:

Present:

RHIC/STAR (USA)
3-200 GeV

SIS18/HADES (Germany)
2.4-2.55 GeV

Future:

HIAF/CEE (China)
2.1-4.5 GeV (2026-?)

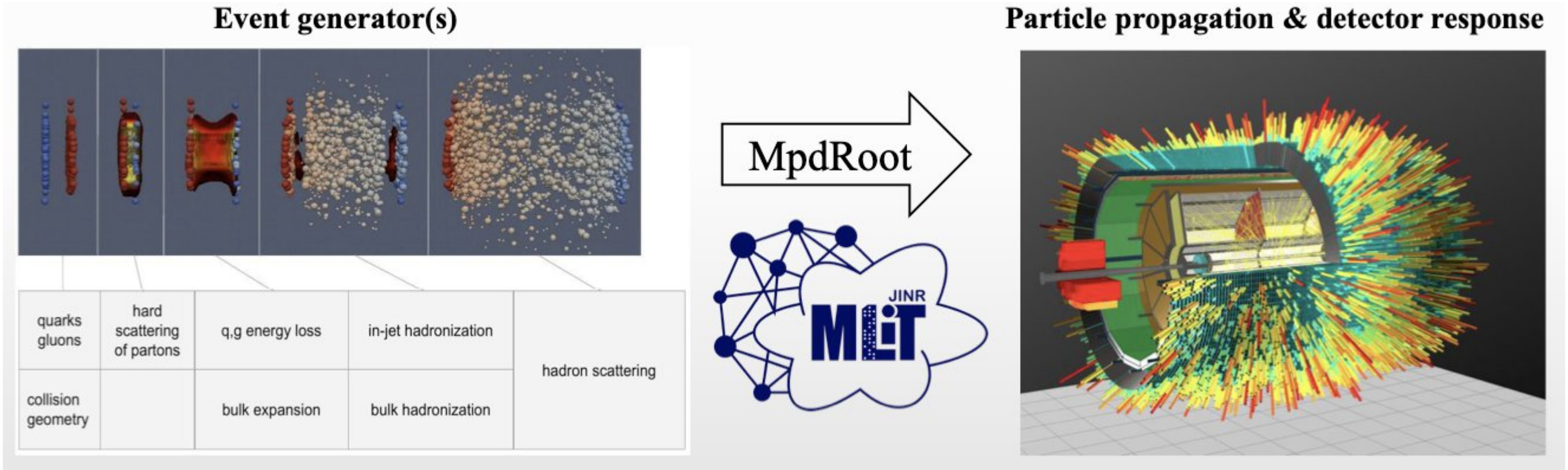
FAIR/CBM (Germany)
2.4-4.9 GeV (2029-?)

JPARC-HI (Japan)
2-5 GeV (2030-?)

MPD at NICA Collider (JINR, Dubna)

MPD NICA:
Multi-Purpose Detector at NICA

MPD Physics Event Simulation at MLIT



The First NICA Collider Data:
MPD Interaction Point
SPD Interaction Point

MPD Interaction Point:

- **The 1st Stage MPD**

MPD-FXT at the 0th Stage:
as soon as NICA in beam operation !

Fall 2026 (?)

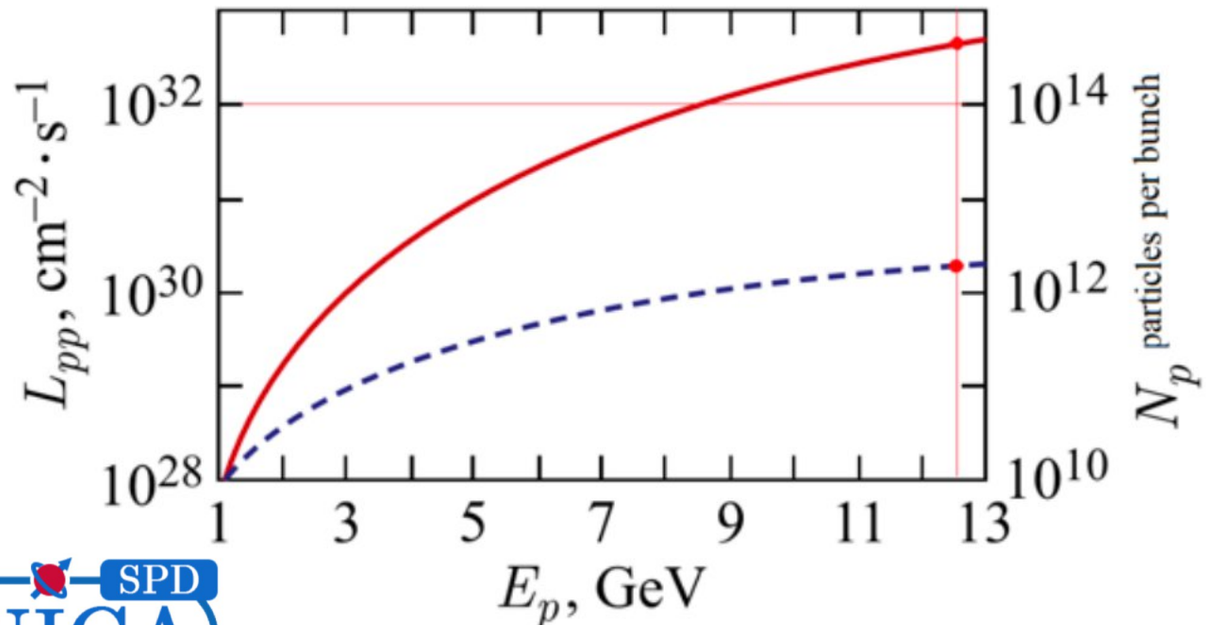
SPD at NICA Collider (JINR, Dubna)

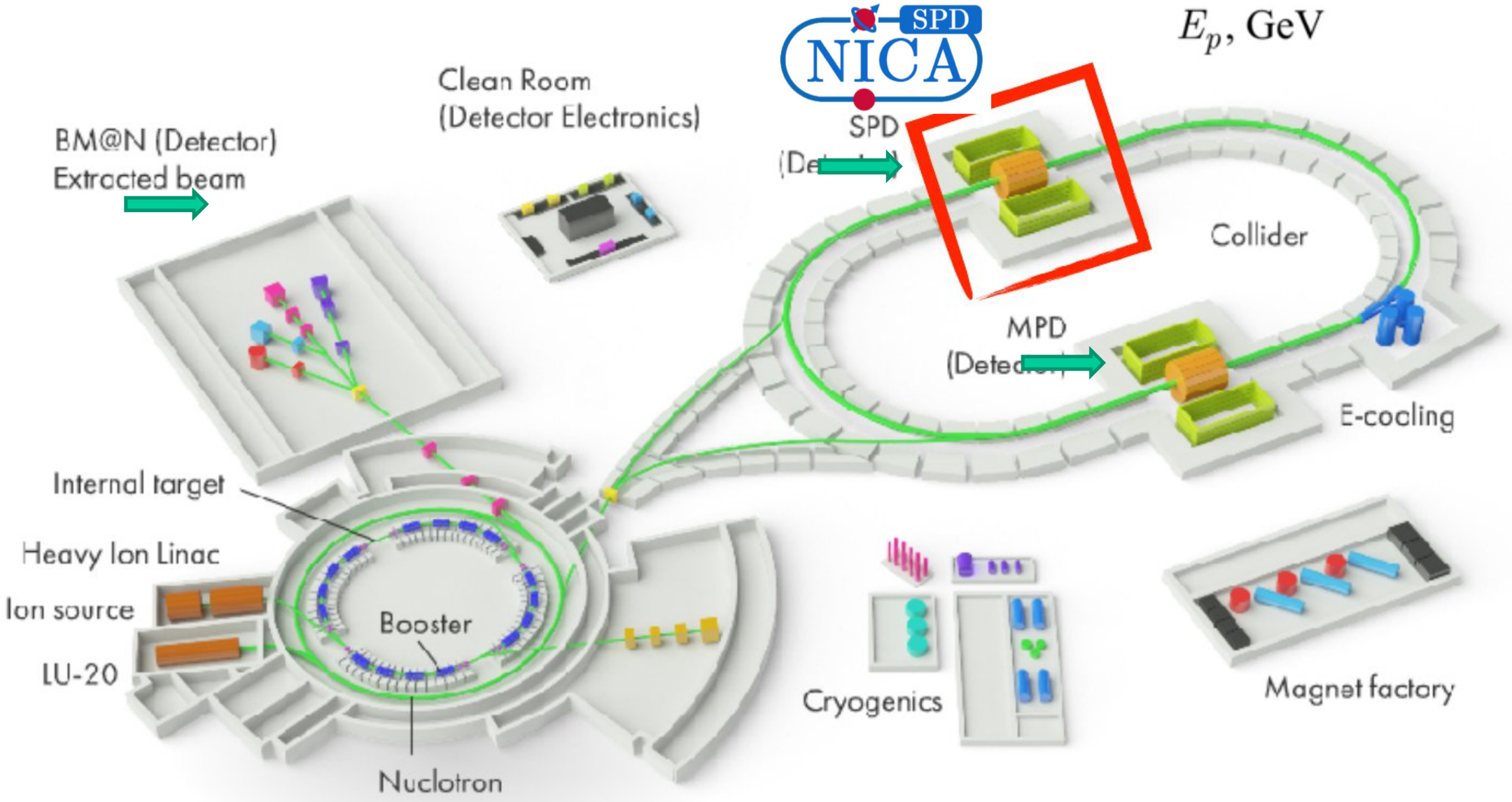
NICA:
Nuclotron-based Ion Collider fAcility

$$p^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 27\ GeV$$
$$d^{\uparrow}d^{\uparrow} : \sqrt{s} \leq 13.5\ GeV$$
$$d^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 19\ GeV$$

U, L, T

|P|>70%





SPD Physics Highlights

► **Spin Physics Detector (SPD) at NICA (http://spd.jinr.ru):**
a universal setup for comprehensive study of
polarized and unpolarized gluon content of proton and deuteron
in polarized and unpolarized high-luminosity pp- and dd- collisions at $\sqrt{s} \leq 27$ GeV

► **Complementing main probes: charmonia (J/Psi, higher states),**
open charm and direct photons in inclusive and semi-inclusive modes

► **SPD can reveal significant insights on:**
- **gluon helicity structure**
- **unpolarized gluon PDF at high x in proton and deuteron**
- **gluon transversity in deuteron**

► **Comprehensive physics program for the initial period of data taking**
(can be performed even at reduced energy and luminosity)

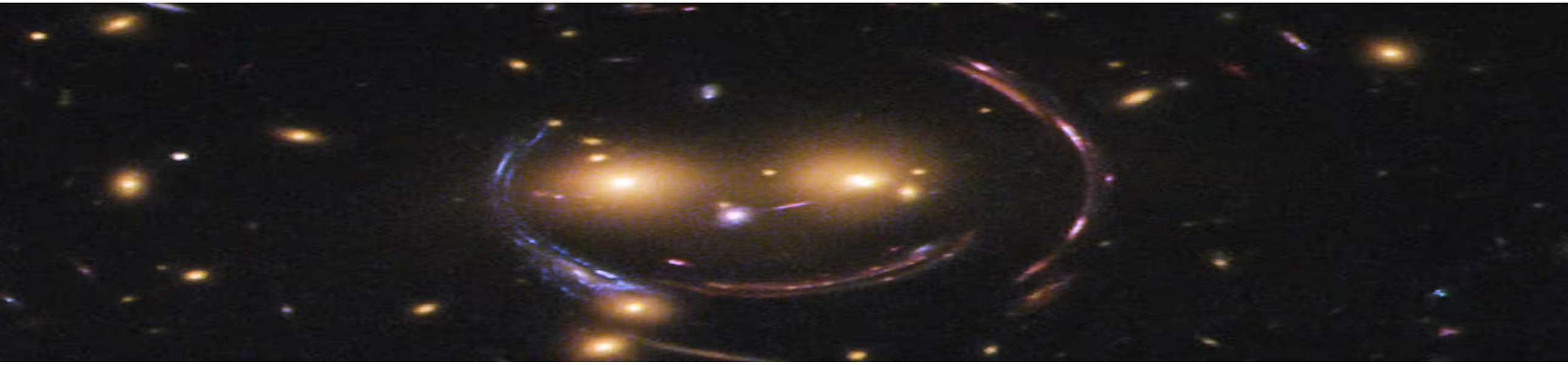
Why Nucleon Spin Physics?

Search for New Physics:

- Search for New Particles and Interactions beyond the Standard Model

- Search for New Dynamics within the Standard Model

Why Nucleon Structure?



- proton mass -> the visible Universe mass

Electroweak Higgs boson provides:

quark mass ~ 15 MeV ≃ 20% of the visible Universe mass

➥ quark-gluon dynamics of nucleon structure provides:

~ 80% of the mass of the visible Universe!

- nucleon size:

quark model ->

huge neutron EDM exceeding 10^12 observed value

Why Spin?

Spin: pure quantum characteristics

spin: no classical analog

spin observables

-> hadron wave functions
-> process amplitudes

“proton spin crisis” :
quark model -> only 1/3 of proton spin

Spin: challenging delicate properties

"Experiments with spin have killed more theories than any other single physical parameter"

Elliot Leader, Spin in Particle Physics, Cambridge U. Press (2001)

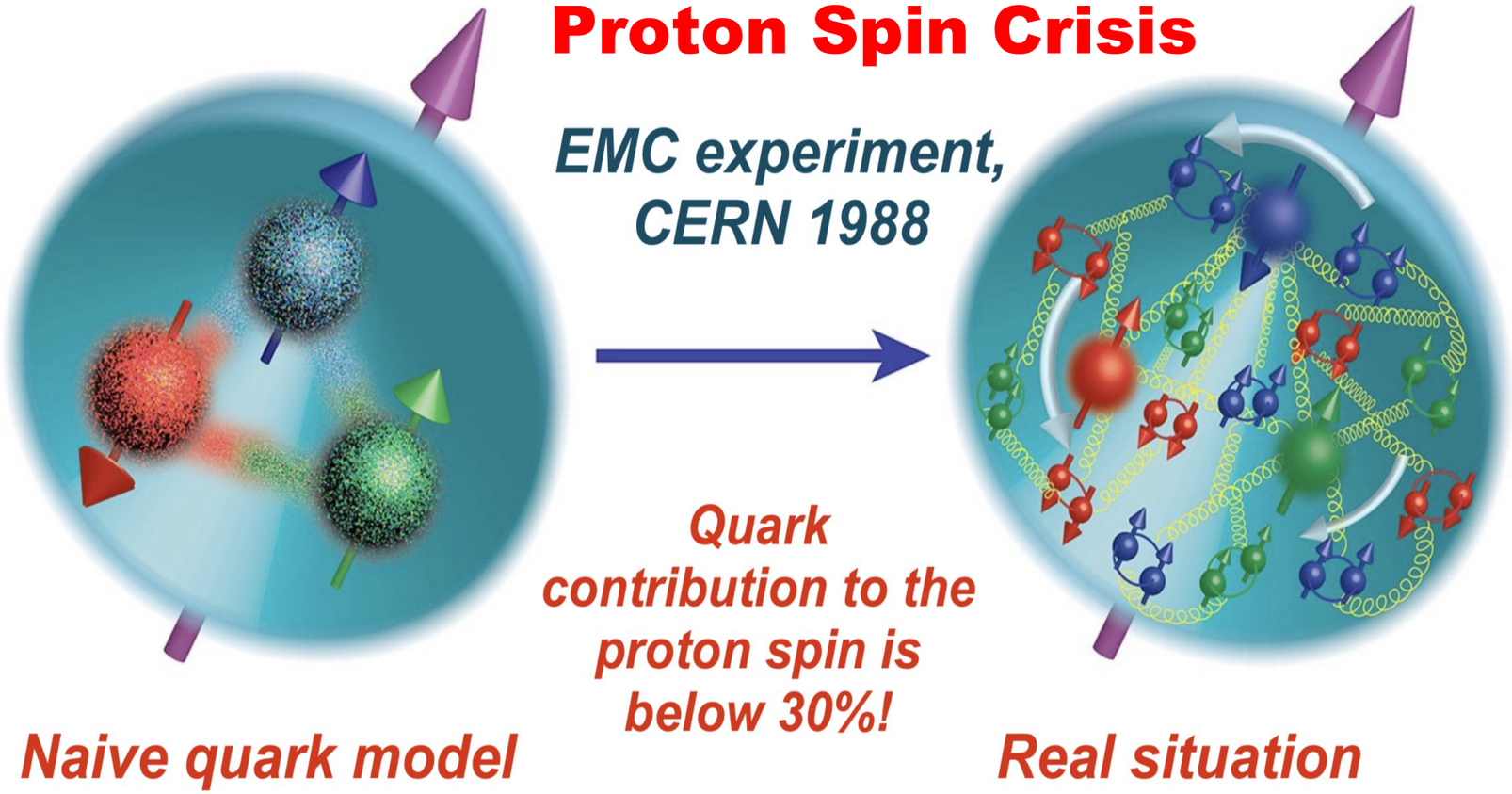
"Polarisation data has often been the graveyard of fashionable theories. If theorists had their way they might well ban such measurements altogether out of self-protection."

J. D. Bjorken, Proc. Adv. Research Workshop on QCD Hadronic Processes, St. Croix, Virgin Islands (1987).

SPD at NICA Collider

Spin Physics Detector (SPD):
polarized pp- and dd- collisions at high luminosity

Proton Spin Crisis



SPD NICA experiment is aimed at studying the properties of strong interactions in the nonperturbative region, at measuring the proton and deuteron spin structures, and at the development of a three-dimensional picture of the nucleon.
SPD NICA is unique in its methodology, breadth of coverage and variety of tasks.

SPD Experiment Main Goals

Spin Physics Detector (SPD) (http://spd.jinr.ru):
A Universal Detector at NICA Collider

➥ **SPD Main Goals:**
understanding strong interactions using polarized
and unpolarized pp- and dd- collisions $\sqrt{s} < 27$ GeV

- 3D structure of proton and deutron, in particular, PDF and TMD at large x

A. Arbuzov et al. ,Prog. Part. Nucl.Phys. 119 (2021) 103858 e-Print: 2011.15005 [hep-ex]

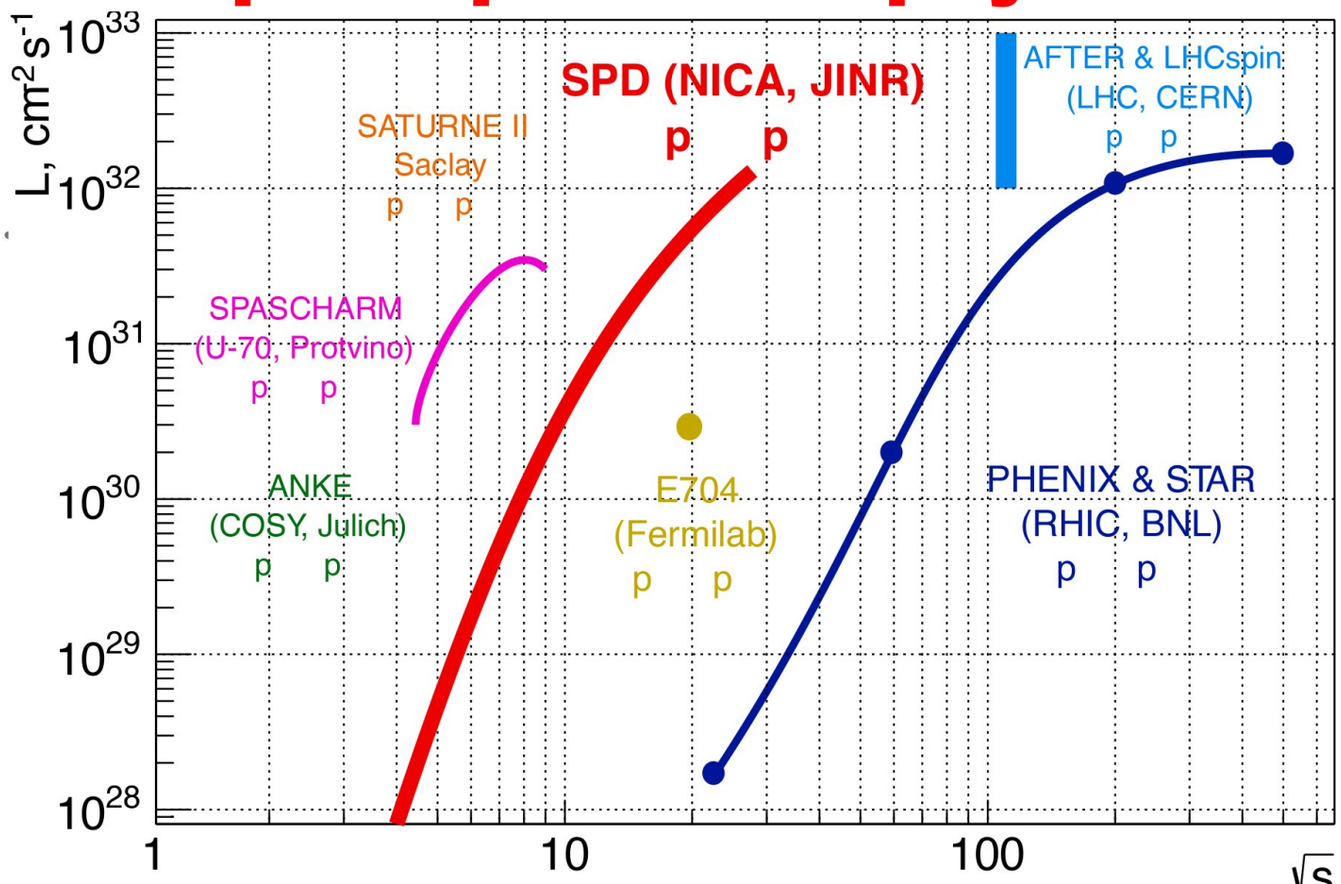
➥ **In addition, wide research program for particular and nuclear physics in the initial 1st Stage of SPD operation is planned**

V.V. Abramov et al., Phys. Part. 52 (2021) 1044, e-Print: 2102.08477 [hep-ph]

TMD - Parton Distribution Function with longitudinal momentum
TMD - Transverse Momentum Distribution–
parton distribution with transverse momentum

SPD in World landscape of polarized physics

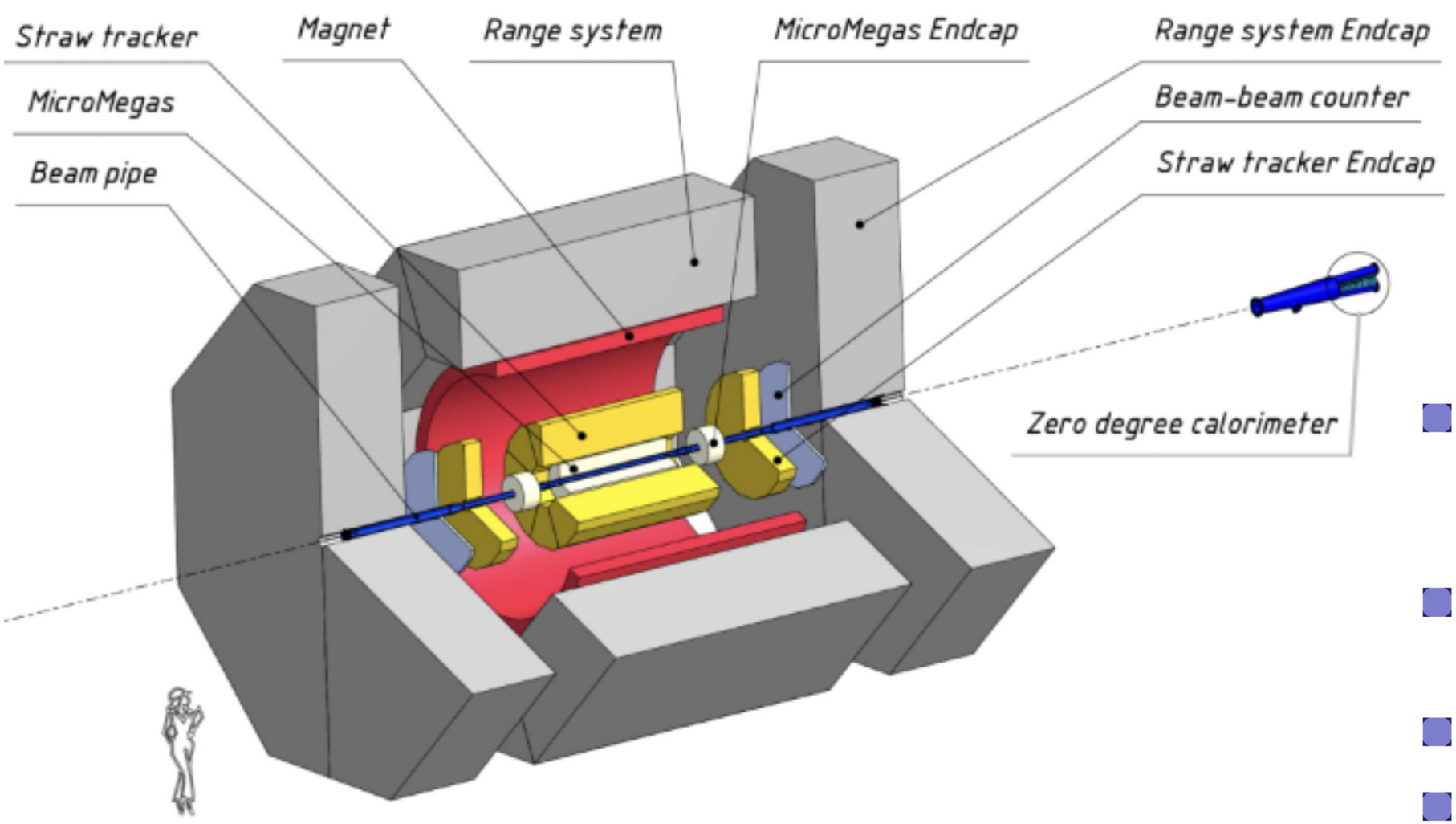
p↑ p↑-mode ➡



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-$d^{\uparrow}$	$p^{\uparrow}$-$p^{\uparrow}$	$e^{\uparrow}$-$p^{\uparrow}$, $d^{\uparrow}$, $^3He^{\uparrow}$	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

⬅ SPD is unique in d↑ d↑-mode!

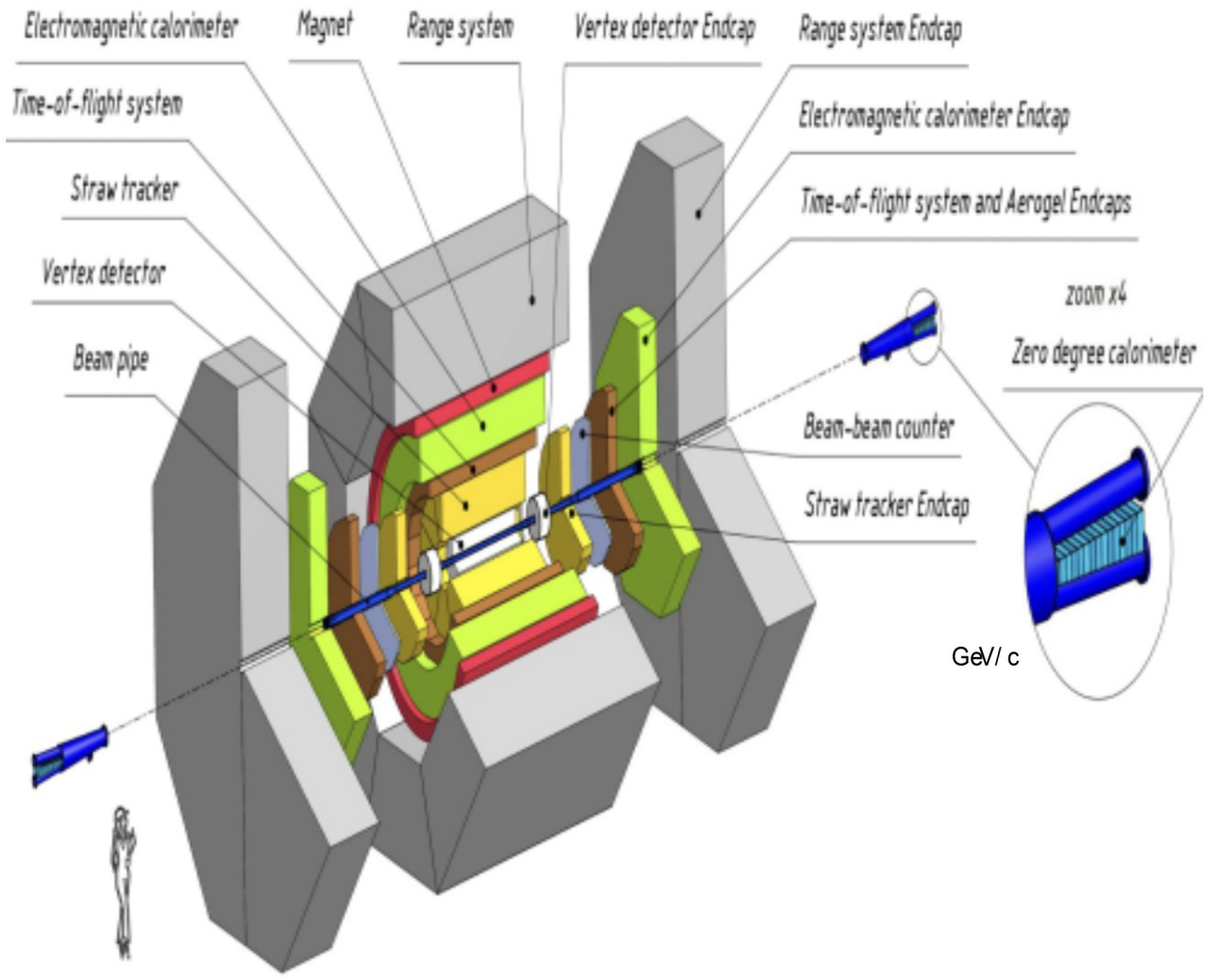
SPD detector at the Stage I



- Trackers:charged track and momentum, limited PID
- Range System:rough hadronic calorimeter, muon/ hadron separation

- Possible light ion collisions alongside pp, dd
- Up to $\sqrt{s}$ =1 0 GeV and reduced luminosity
- Solenoidal field B 1T
- BBC and ZDC for online polarimetry
- Micromegas central tracker
- Straw Tracker 150 m, $(\frac{dE}{dx})$= ←.5%

SPD detector at the Stage II



- Event rate at peak luminosity and energy
  3M Hz
- Silicon vertex detector : MAPS/ DSSD
- Time of ight (TOF) for PID (t 50 ps), $/K$ separation upto 1.5 GeV/ c
- Electromagnetic calorimeter (ECAL) ($\frac{E}{E}$ = $\frac{5\%}{p\overline{E}}$ +1 %)
- Aerogel counter in endcaps,extends $/K$ separation upto 2.5GeV/ c

- Improved vertex detector for short lived particle decays
- TOF+A GeI for better PID
- ECAL for , e identification

SPD detector data flow

No hardware trigger at the SPD detector to avoid a possible bias:
3 MHz event/s at 10^{32} cm^2/s design luminosity
20 GB/s ➡ 3 10^3 events/year ➡ 200 PB/year

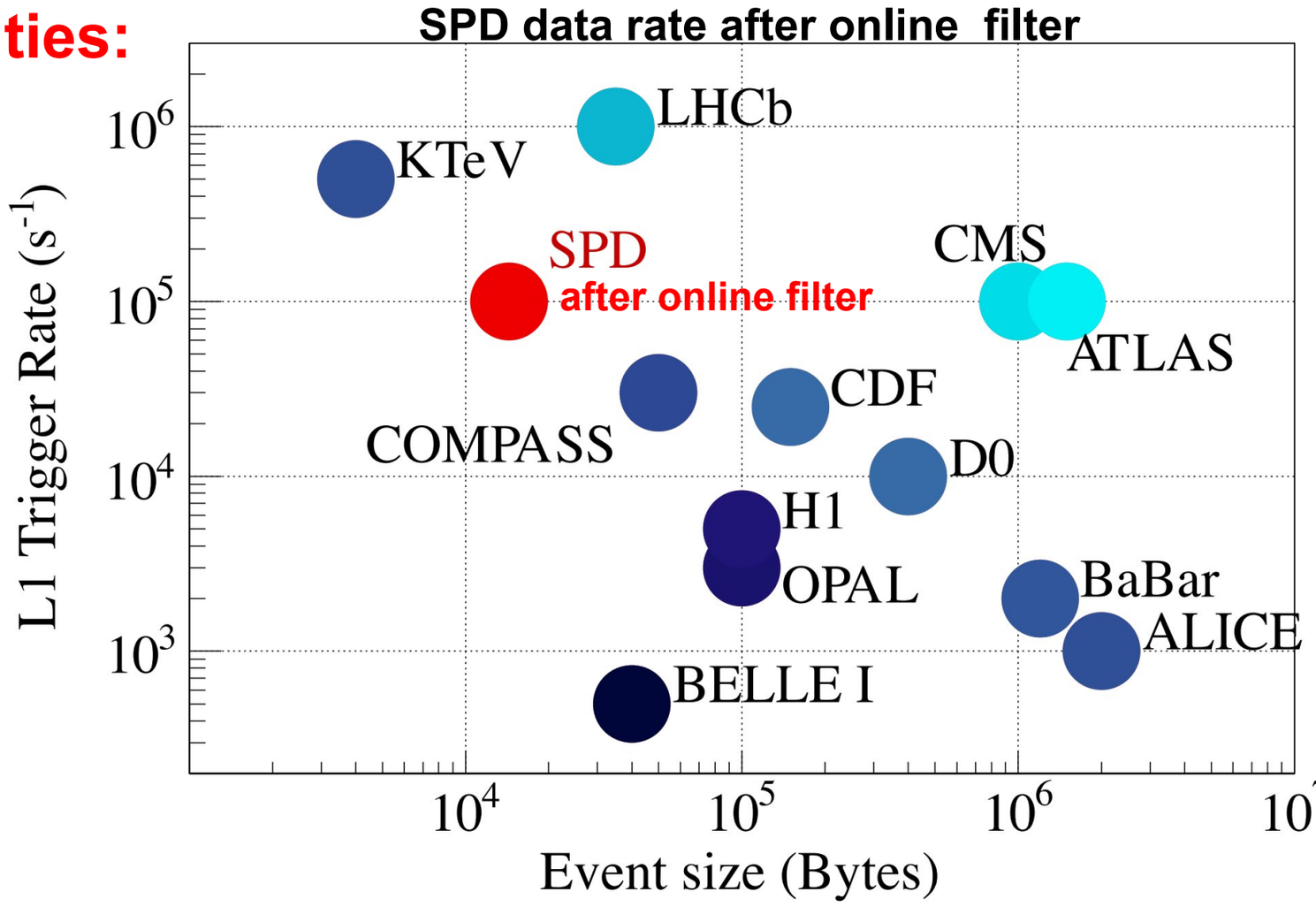
The SPD setup is a medium scale detector in size,
but a large scale one in data rate!
Comparable in data rate with ATLAS and CMS at LHC

SPD Tier-1 Prototype Facilities:

- **NRC KI - PNPI, Gatchina**
- **SSU, Samara**

Towards SPD GRID

SPD Grid Sites:
- **LIT JINR**
- **NRC KI – PNPI, Gatchina**
- **SSU, Samara**



SPD Collaboration: established in July 2021

Spin Physics Detector

SPD NICA

The NICA-SPD Collaboration, July 2021

SPD Collaboration: Organization

40 organizations from 15 countries > 400 participants

Signed MoU:

NRC "Kurchatov Institute" - PNPI, Gatchina
Alikhanov National Science Laboratory (Yerevan Physics Institute), Yerevan
Samara National Research University, Samara
Peter the Great Saint Petersburg Polytechnic University, St. Petersburg
Saint Petersburg State University, St. Petersburg
Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow
Lebedev Institute of Physics RAS, Moscow
Institute for Nuclear Research RAS, Moscow
Institute of Nuclear Physics (INP RK), Almaty
Tomsk State University, Tomsk
National Research Nuclear University MEPhI, Moscow
Belgorod State University, Belgorod
Institute of Nuclear Problems, Belorussian State University, Minsk
Budker Institute of Nuclear Physics RAS, Novosibirsk
Higher Institute of Technologies and Applied Sciences, Havana
Higher School of Economics, Moscow
in signing: I-Temba Labs (South Africa), Univ. Cairo (Egypt)
New member: Shandong Univ. (China)

SPD Co-Spokespersons:
A.V. Guskov (JINR) & V.T. Kim (NRC KI - PNPI)

CB Chair: A. Tumasyan (AANL, Yerevan)

SPD Collaboration Meetings:
prior 2023: Dubna
2023: Dubna (April)
Samara (October)
2024: Almaty (May)
Dubna (November)
2025: Yerevan (May)
Dubna (October)
2026: Tomsk (May)
Dubna (October?)

SPD at NICA Collider (JINR, Dubna)

SPD NICA:
Spin Physics Detector at NICA

The 1st Stage of SPD: Under R&D
Beam-ready at 2030+

SPD Collaboration:
Co-Spokesperson: Alexey A. Guskov (JINR)
Co-Spokesperson: Victor T. Kim (NRC KI - PNPI)

Participants > 400
Organizations: 40
Countries: 15

SPD Physics:

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], F. Murgia [h], M. Nefedov [l], B. Parsamyan [a, n, o], C. Pisano [g, h], M. Radici [c], A. Rymbekova [a], V. Saleev [l, a], A. Shipilova [l, a], Qin-Tao Song [s], O. Teryaev [a]

ArXiv e-Print: 2011.15005 [hep-ex]

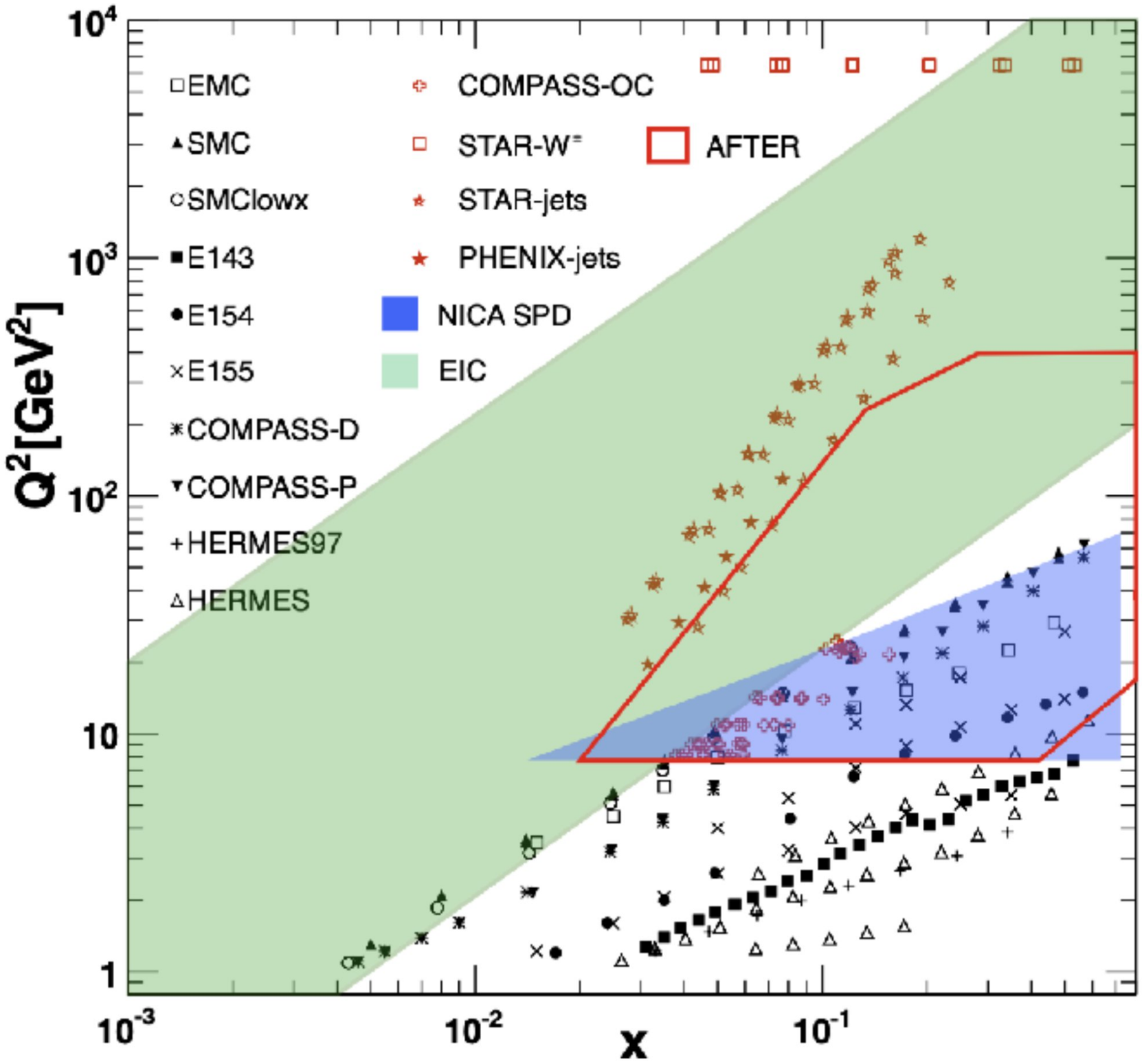
Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams

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, ←], E. Kokoulina [5, ↳], 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 [7, 1↵], P. Yu. Shatunov [10, 11], Yu. M. Shatunov [10, 11], O. V. Selyugin [14], M. Strikman [1↳], E. Tomasi-Gustafsson [20], V. V. Uzhinsky [13], Y u. N. Uzikov [6, 21, 22, ⋆], Qian Wang [23], Q iang Zhao [24, 25], A. V. Zelenov [7]

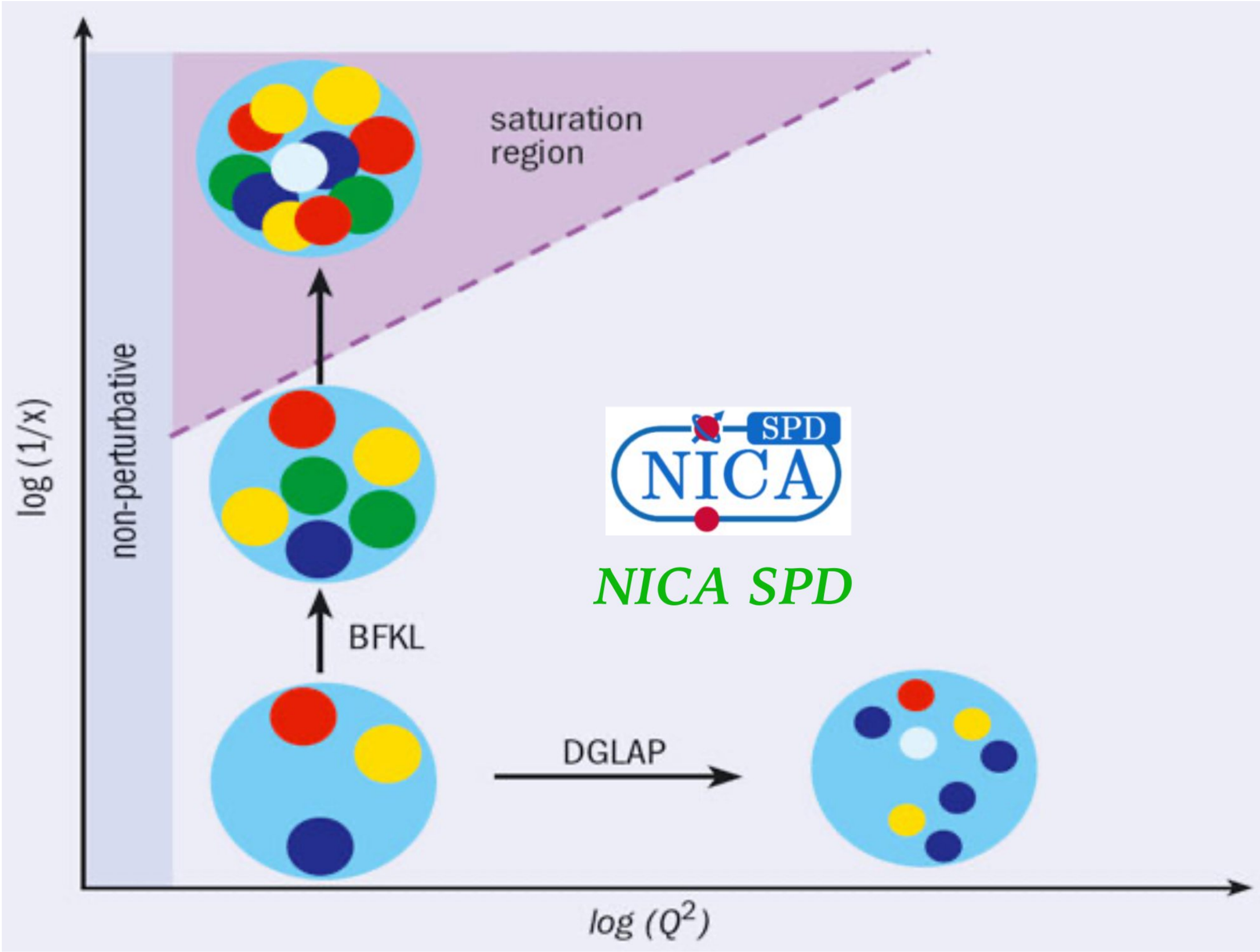
Phys. Part. Nucl. Vol.52, 2021, 1044

ArXiv e-Print: 2102.08477 [hep-ph]

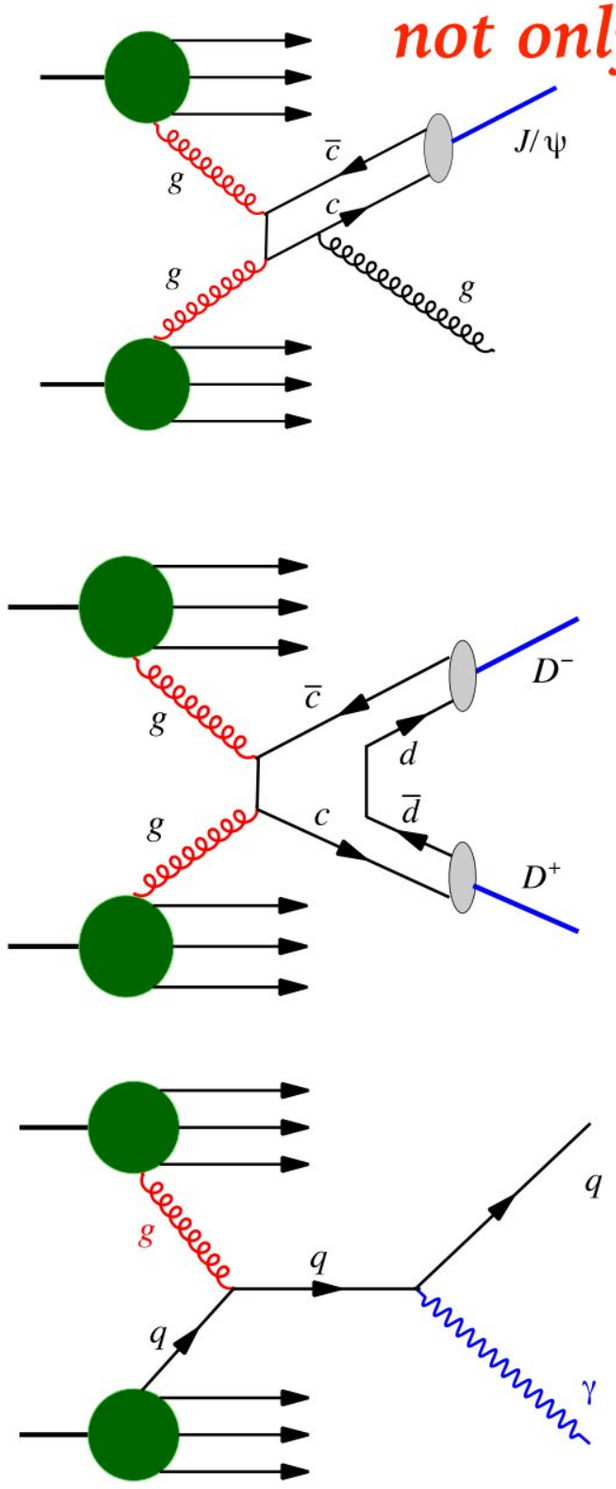
PDF kinematic range



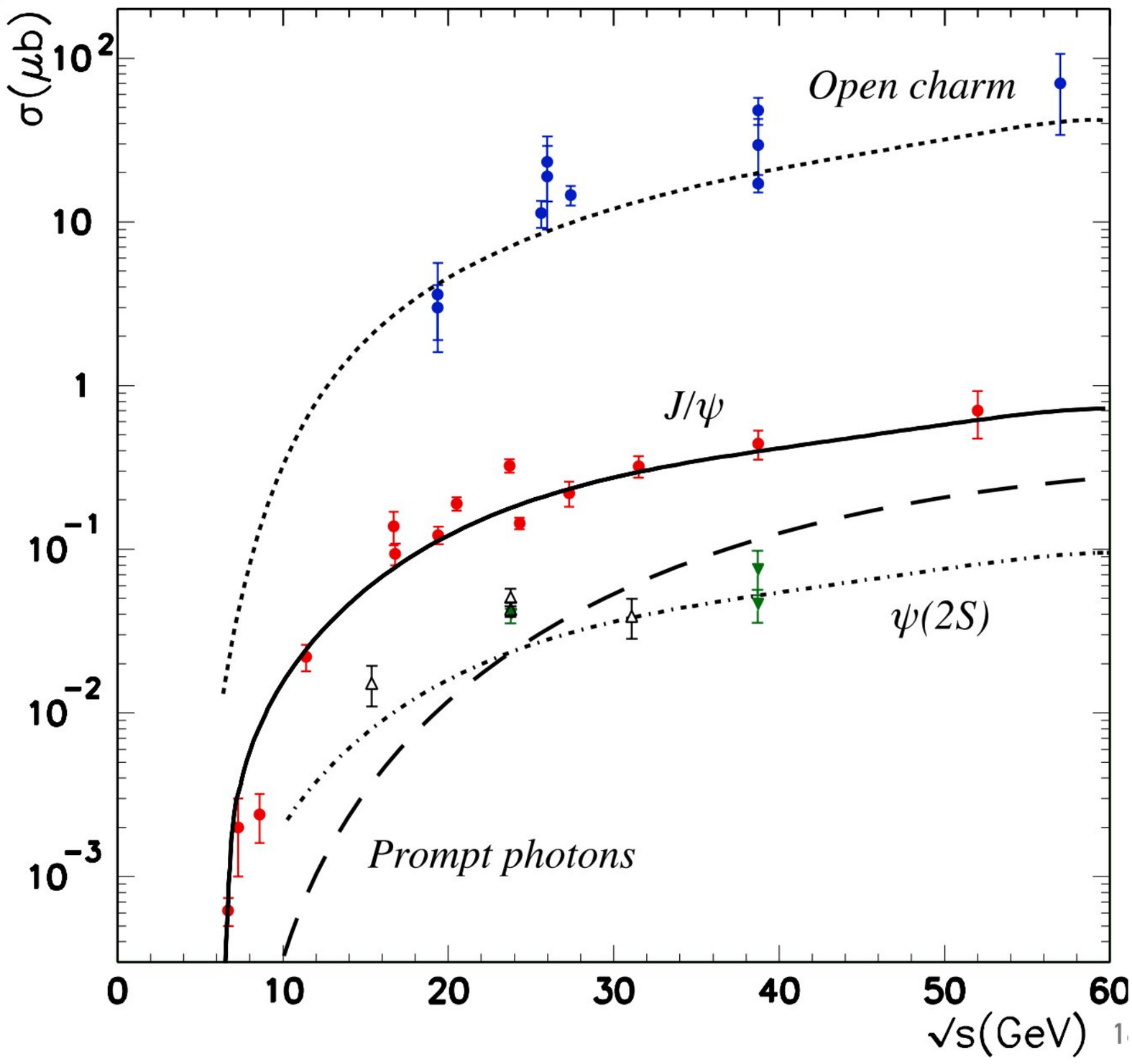
Dynamics kinematic range



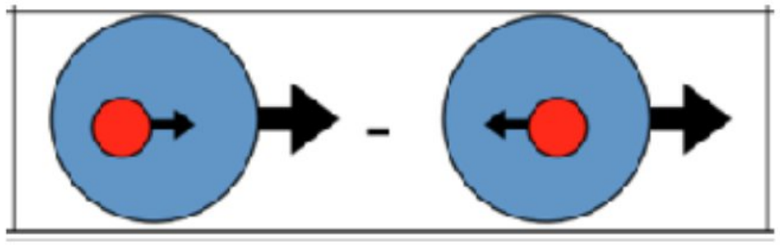
Gluon probes at SPD: charmonia, open charm, direct photons



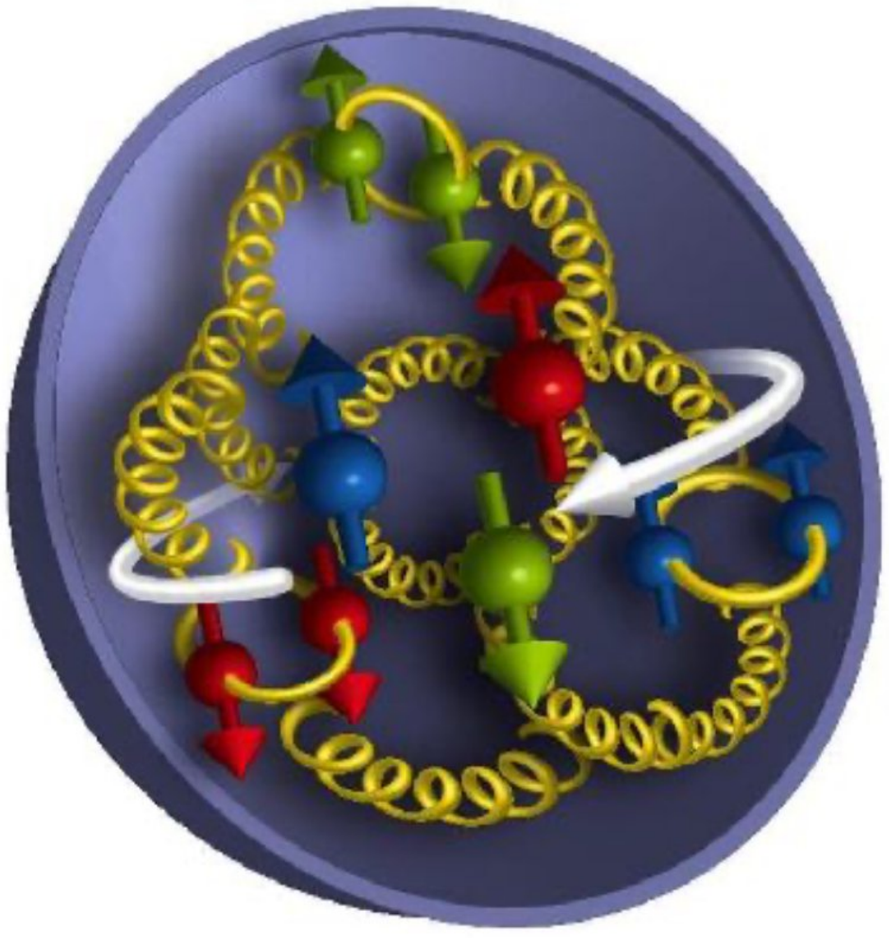
$$\sigma = PDF_1 \otimes PDF_2 \otimes \hat{\sigma}_{12}$$

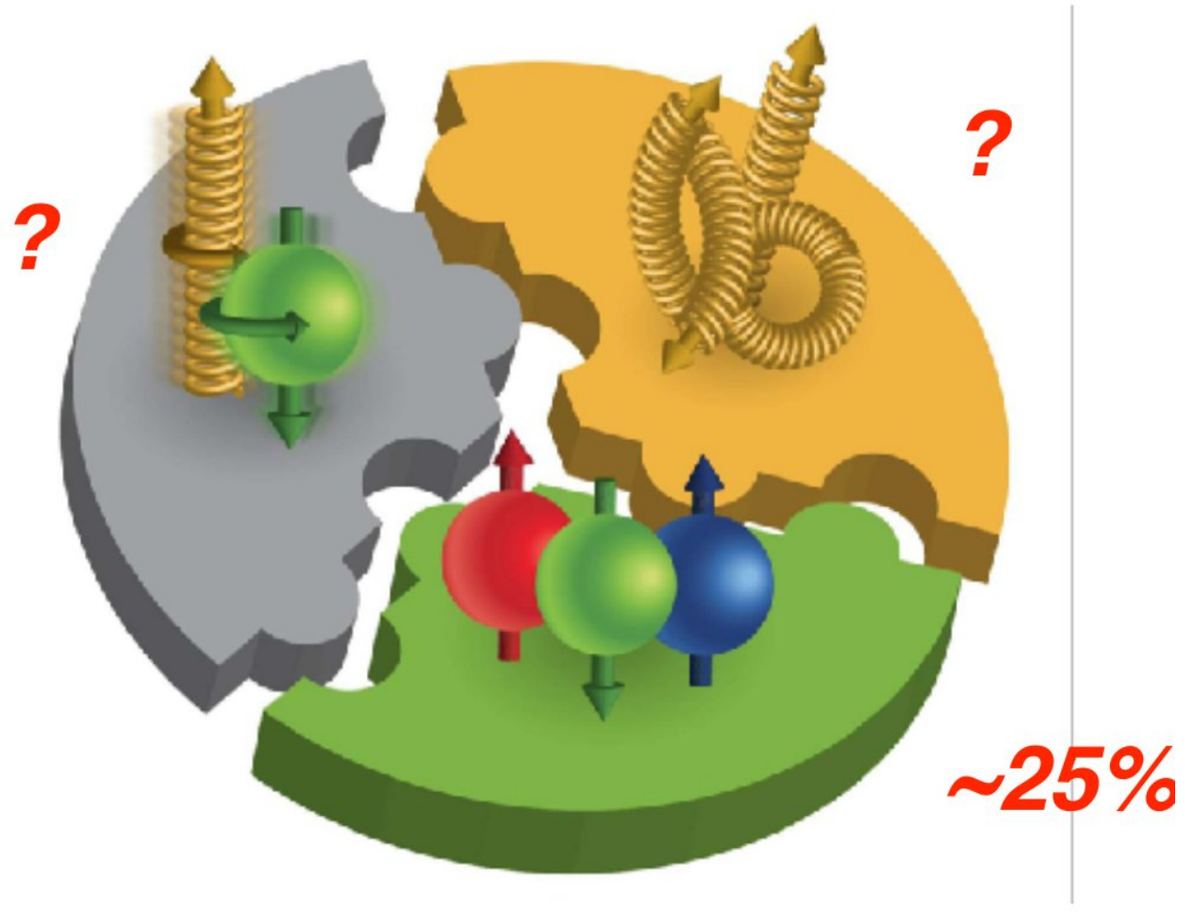


Helicity gluon PDF Δg(x): Spin Crisis

g(x) : 

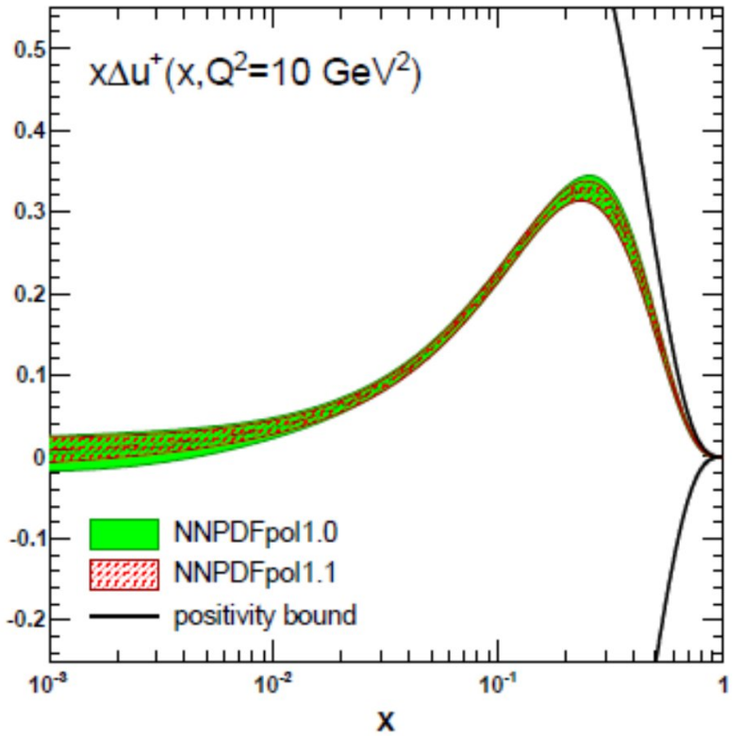
$$\Delta G = \int_0^1 \Delta g(x) dx$$

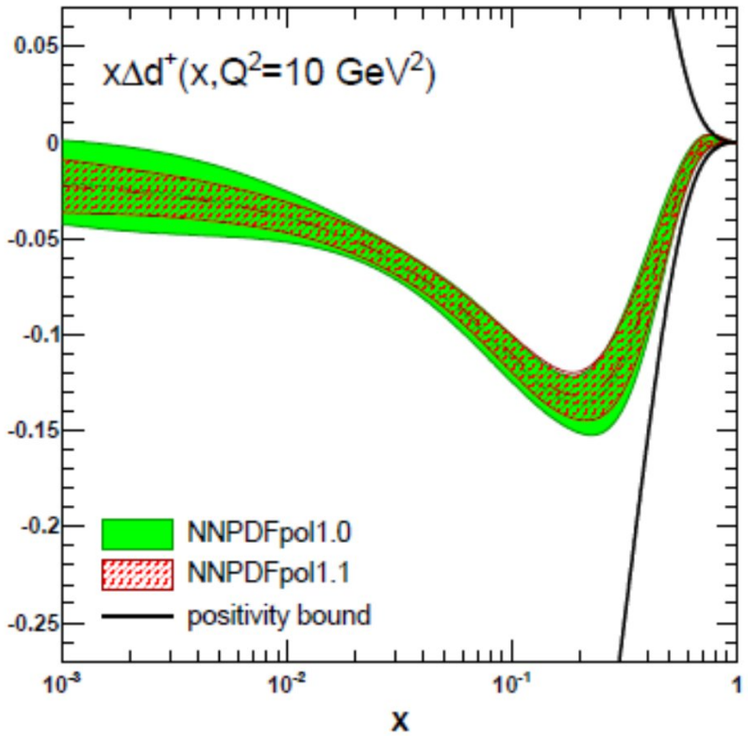


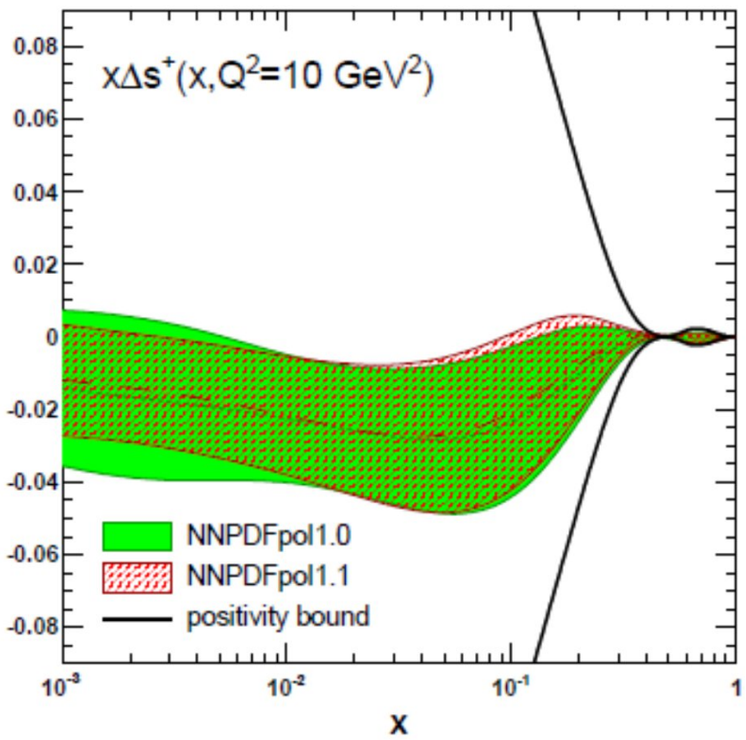


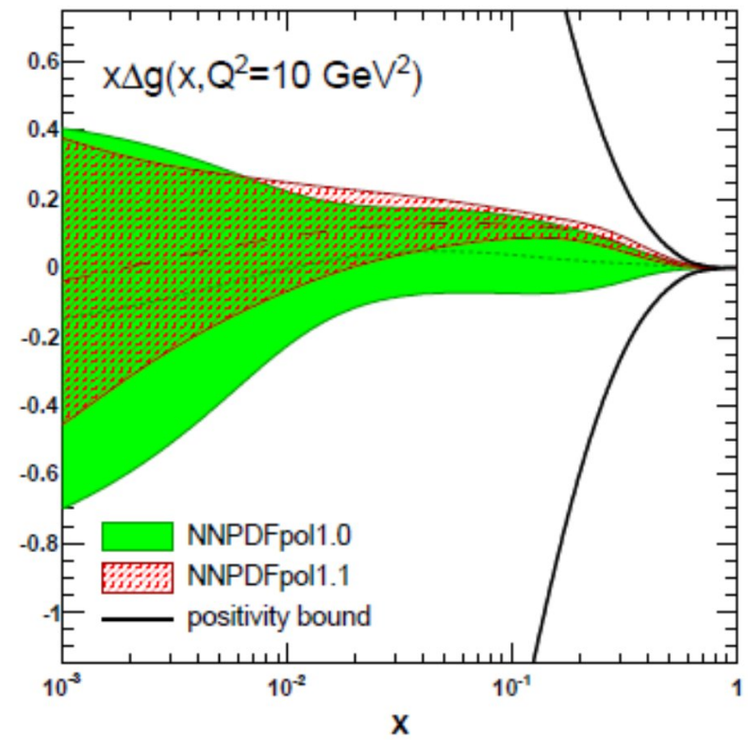
$$S_N = ½ = ½\,\Delta\Sigma + \Delta G + L$$

NNPDF Coll.: quark and gluon helicity PDFs of proton









NNPDF Coll.:
E. Nocera et al. (2014)

Quark helicity PDF:
few percent level uncertainties

It is measured with high precision in DIS

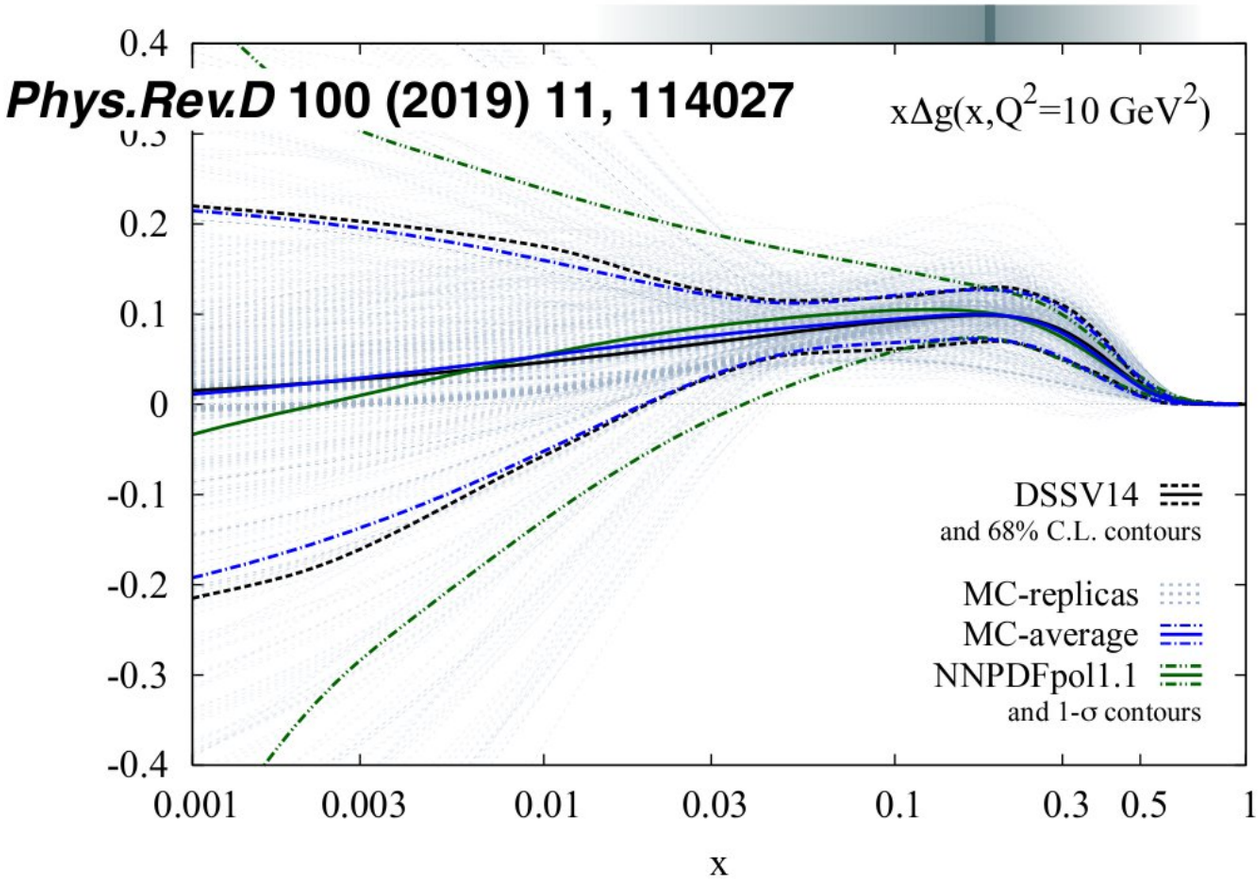
Gluon helicity PDF:
still rather high uncertainties!

Hadron collisions have a better sensitivity to measure it.

⬅ SPD has a good opportunity!

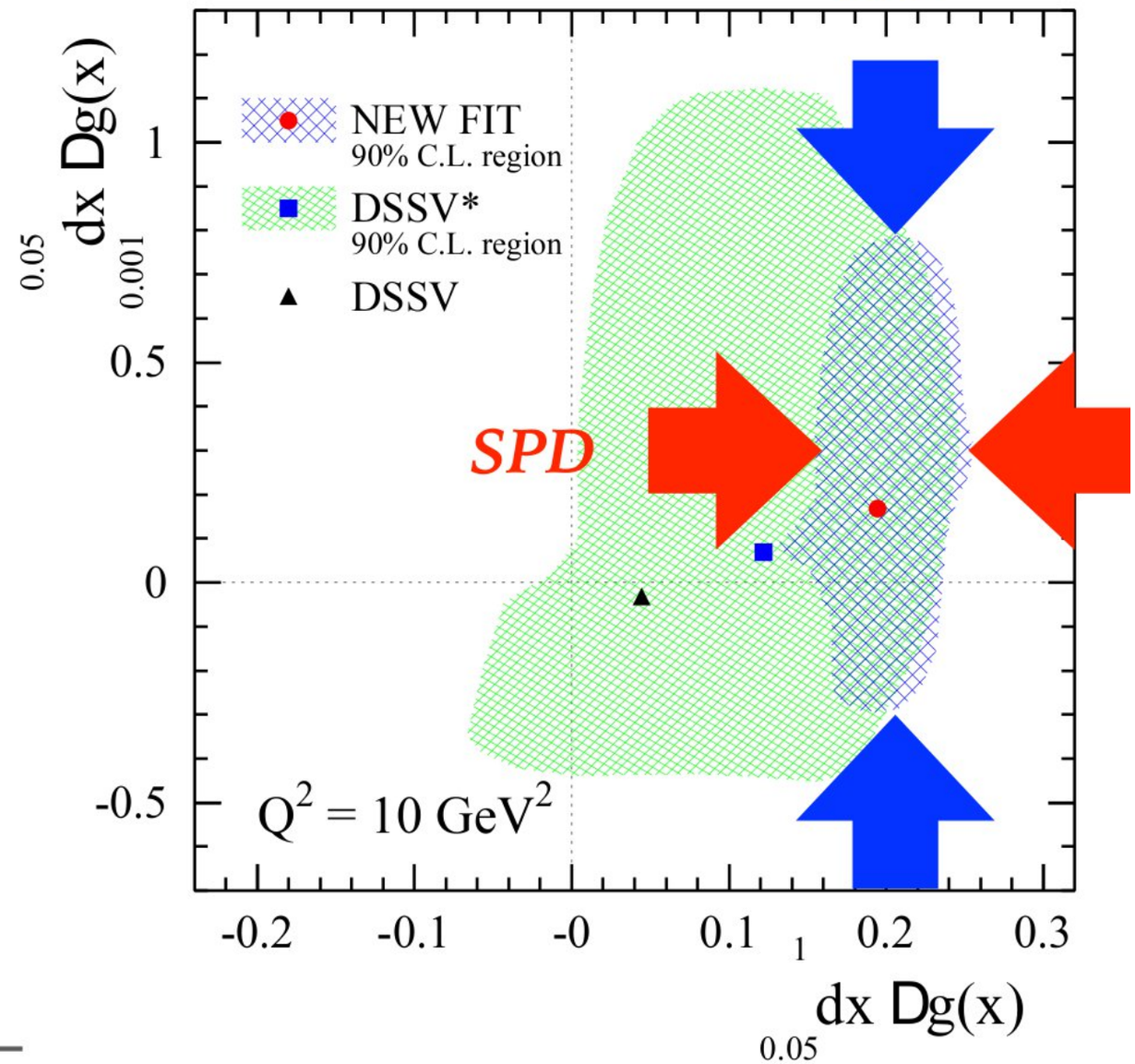
Helicity gluon PDF Δg(x):

accessible with SPD



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

EIC

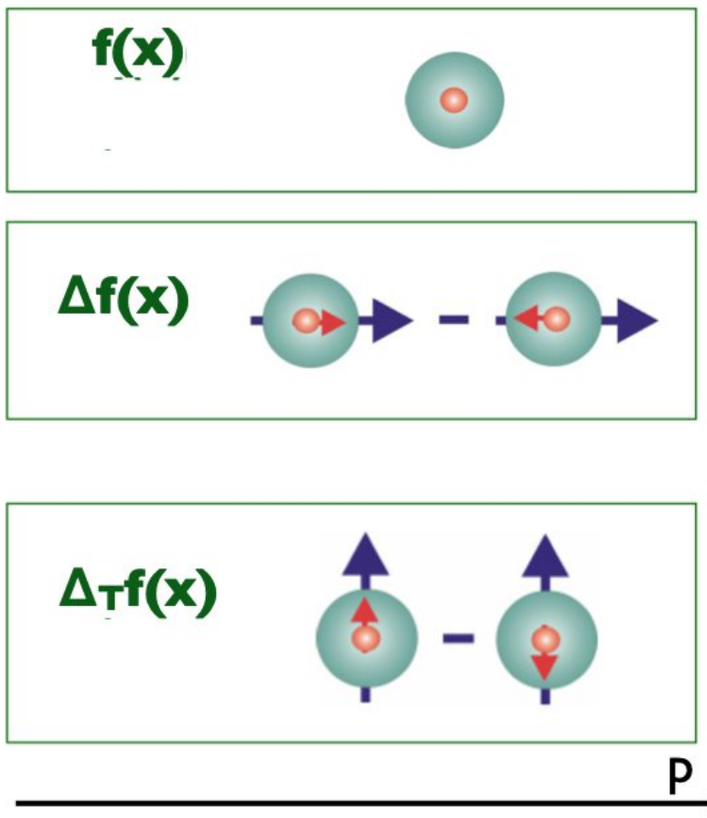


SPD could help to r educe uncertainty of G at large x

$$A_{LL} = \frac{\sigma^{++} \quad \sigma^{+}}{\sigma^{++} + \sigma^{+}}$$

$$A_{LL}^{cc} \approx \frac{\Delta g(x_1)}{g(x_1)} \otimes \frac{\Delta g(x_2)}{g(x_2)} \otimes \hat{a}_{LL}^{gg \to ccX} \qquad A_{LL}^{\gamma} \approx \frac{\Delta g(x_1)}{g(x_1)} \otimes A_{1p}(x_2) \otimes \hat{a}_{LL}^{gq(q) \to \gamma q(q)} + (1 \leftrightarrow 2)\,.$$

Spin of proton



Unpolarized PDF

Helicity

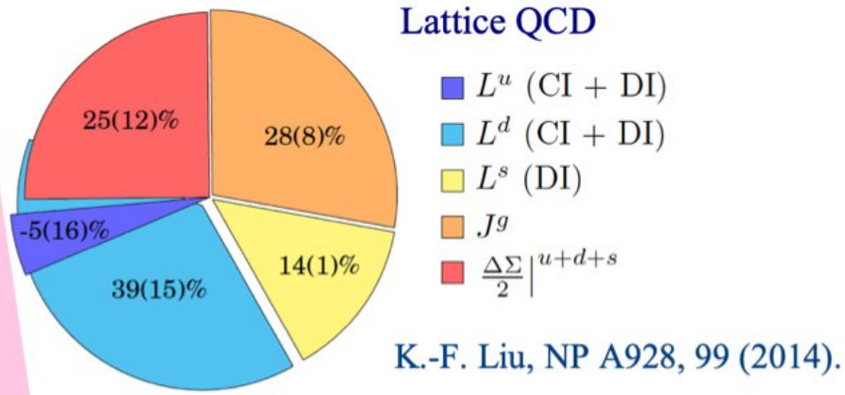
Transversity

$$J = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

~30%

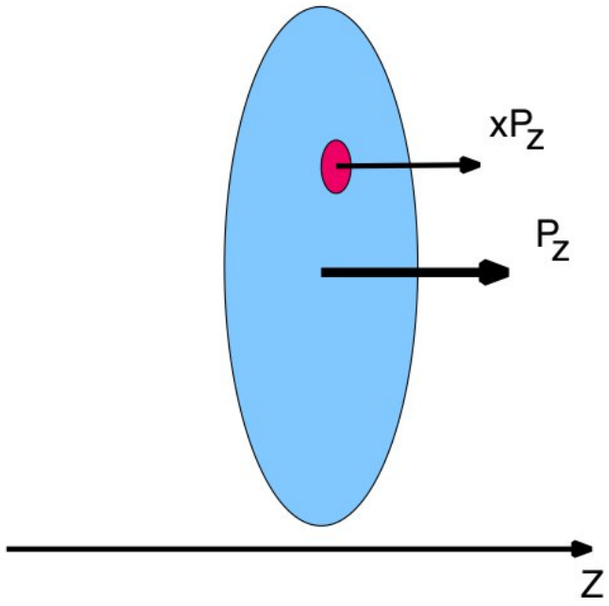
~10-20%

? ?



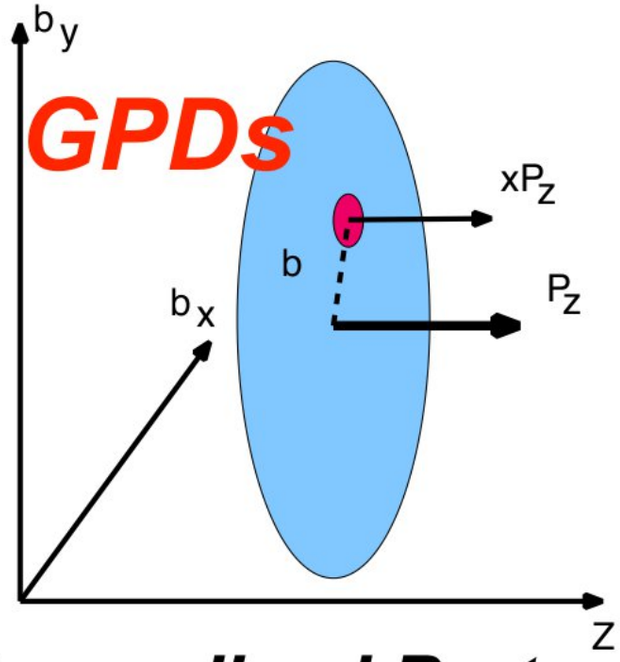
To access angular momenta info about 3D structure is needed!

SPD: towards 3D-structure of nucleon

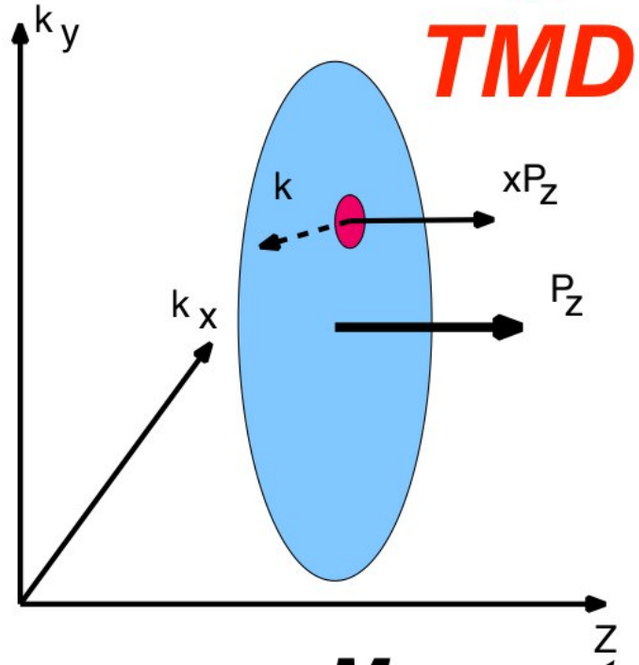


Collinear approximation

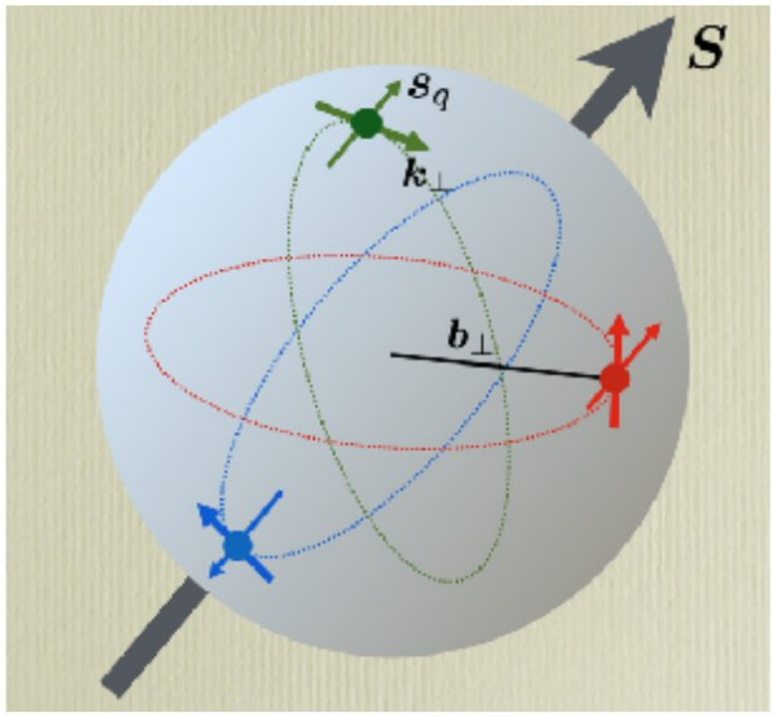
(common PDF)



Generalized Parton Distributions



Transverse Momentum Dependent PDFs



3D structure of nucleon

connection to orbital moment

13

TMD: quarks in polarized nucleon

Nucleon (N) with momentum P and spin polarization S=(U,L,T)

New information in quark TMD of nucleon: $\Phi^q(x, P, S)$

$\Phi^q(x, P, S)$ contains time-even functions:

$f^q(x, kT)$ ⬅ unpolarized quarks in unpolarized N ⬅ density

$g^g_L(x, kT)$ ⬅ L-polarized (chiral) quarks in L-polarized N ⬅ helicity

$g^g_T(x, kT)$ ⬅ L-polarized (chiral) quarks in T-polarized N ⬅ worm-gear

$h^q_T(x, kT)$ ⬅ T-polarized quarks in T-polarized N ⬅ pretzelocity

and time-odd functions (spin-orbital correlations):

$f^{\perp g}_L(x, kT)$ ⬅ unpolarized quarks in T-polarized N ⬅ Sivers f.

$h^{\perp q}_T(x, kT)$ ⬅ T-polarized quarks in unpolarized N ⬅ Boer-Mulders f.

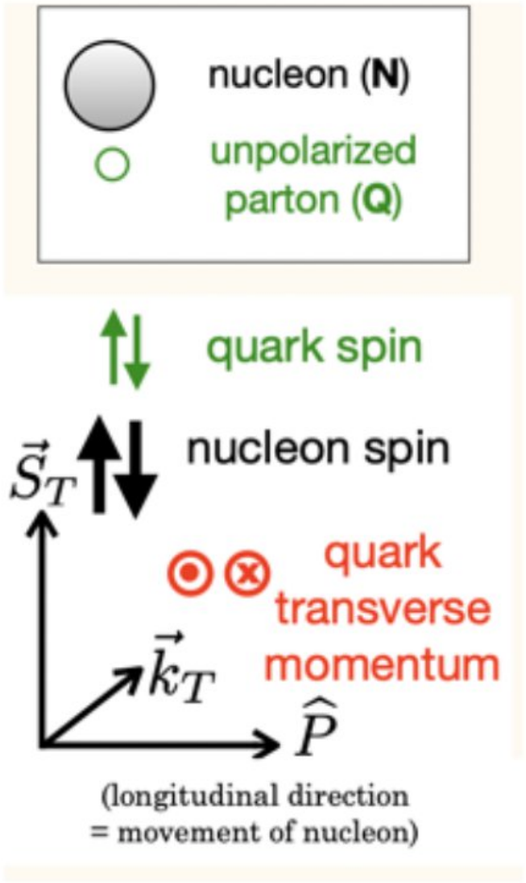
Integrated over kT quark TMDs:

$f^q(x) = q(x) = q_{L=+}(x) + q_{L=-}(x)$

$g^q_L(x) = \Delta q(x) = q_{L=+}(x) - q_{L=-}(x)$ ⬅ helicity (chirality)

$h^q_T(x) = \delta q(x) = q_{T=+}(x) - q_{T=-}(x)$ ⬅ transversity

TMDs: quarks in nucleon



N \ Q	U	L	T
U	f_1 number density		$h_1^\perp$ Boer-Mulders
L		g_1 helicity	$h_{1L}^\perp$ worm-gear
T	$f_{1T}^\perp$ Sivers	$g_{1T}^\perp$ worm-gear	h_1 transversity; $h_{1T}^\perp$ pretzelosity

Gluon TMD with SPD

Unpolarized gluons at high x in proton and deuteron

Gluon helicity

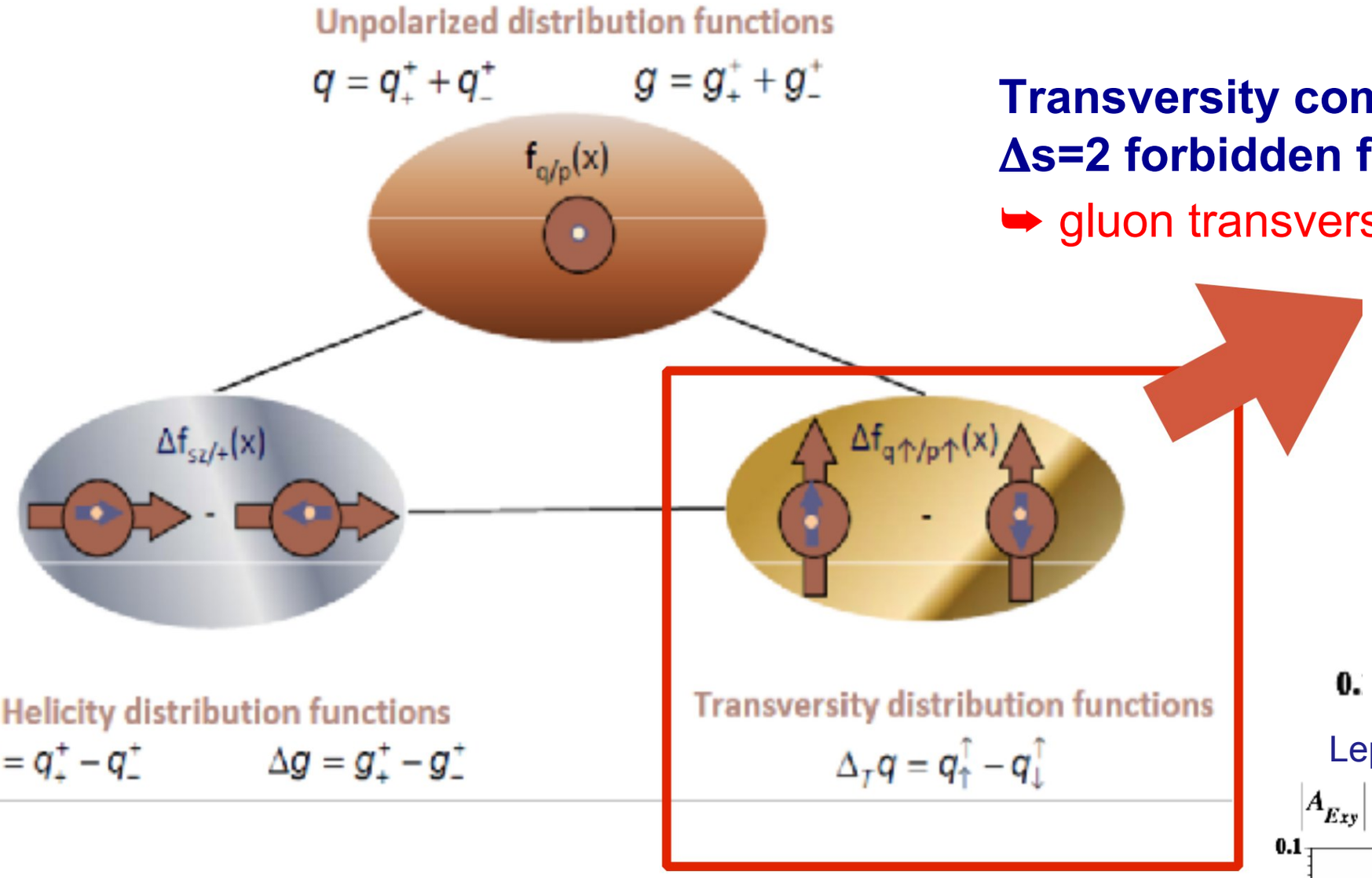
Gluon Boer-Mulders function

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	$h_{1T}^g, h_{1T}^{\perp g}$

Gluon Sivers function

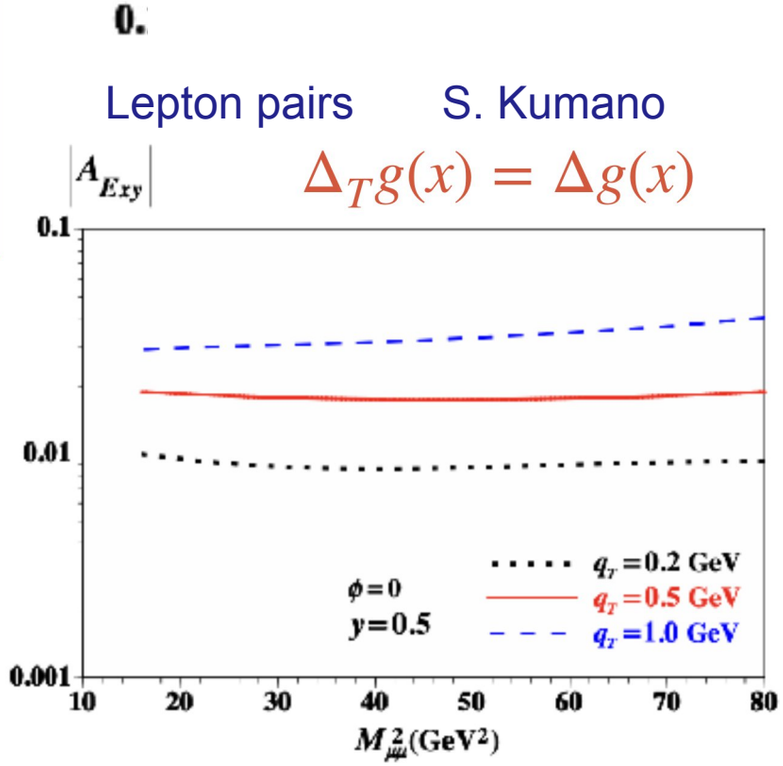
Gluon transversity in deuteron

Gluon transversity of deuteron



Transversity comes from spin-flip:
Δs=2 forbidden for spin-½ nucleon in LO

➥ gluon transversity in nucleon ≈ 0



SPD has a unique opportunity to measure
gluon transversity in deuteron for the first time!

To probe new non-nucleonic degrees of freedom in deuteron!

SPD Physics at the 1st Stage

V.V. Abramov et al., Phys. Part. Nucl. 52(2021) 1044, e-Print: 2102.08477 [hep-ph]

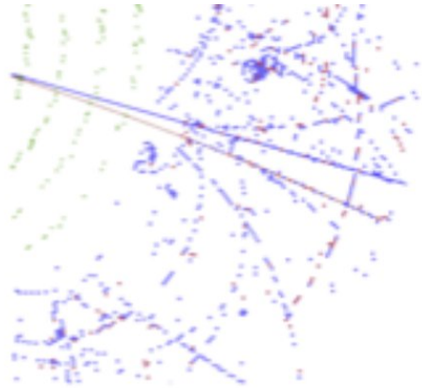
Comprehensive and rich physics program at the initial stage of SPD data taking:

- **Spin effects in pp-, pd- and dd- (quasi)elastic scattering**
- **Spin effects in hyperon production**
- **Search for exotic states (glueball, penta- and tetra- quarks)**
- **Multiquark correlations (SRC) in deuteron and light nuclei**
- **Dibaryon resonances**
- **Hypernucleus production**
- **Open charm and charmonia production near threshold**
- **Large-pT hadron production to study diquark structure of proton**
- **Large-pT hadron production to study multiparton scattering**
- **Antiproton production measurement for astrophysics and BSM search**
- **…**

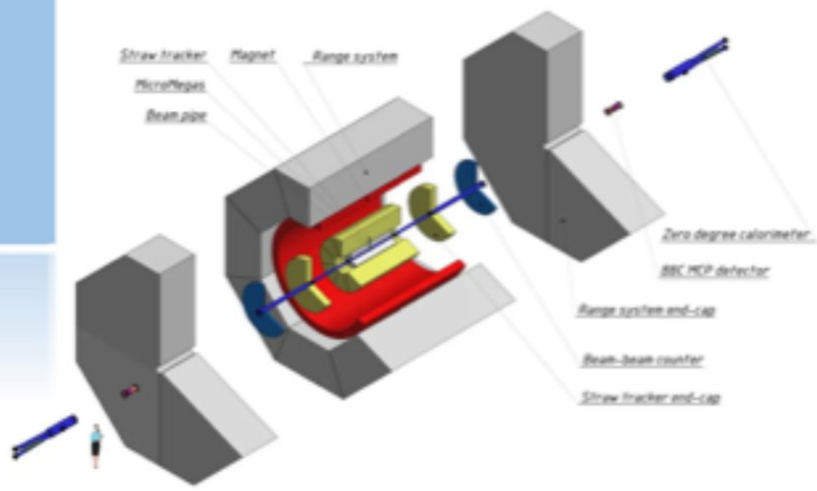
The 1st Stage of SPD Physics Update: Workshop

- 14 proposed measurements
- > online 60 participants

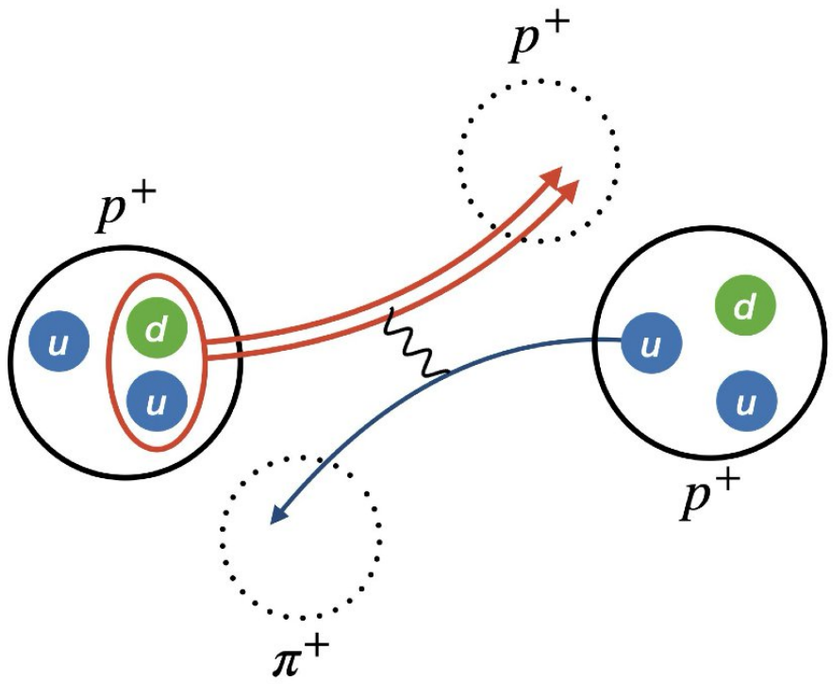
We invite you for the discussion of existing elaborated SPD proposals



SPD first stage physics workshop



SPD Physics at the 1st Stage: exotic states pentaquark, dihyperon, tetraquark, etc. production



Diquarks:

– **proton production scaling violation**
V.K. 1988

– **exotic multiquark state production**
A. Efremov, V.K. 1987
V. Abramov et al 2021

Diquarks:
tetraquark production a(980)?: ~ 5-10% of large-pT proton production
V.K., A.V. Zelenov 2025

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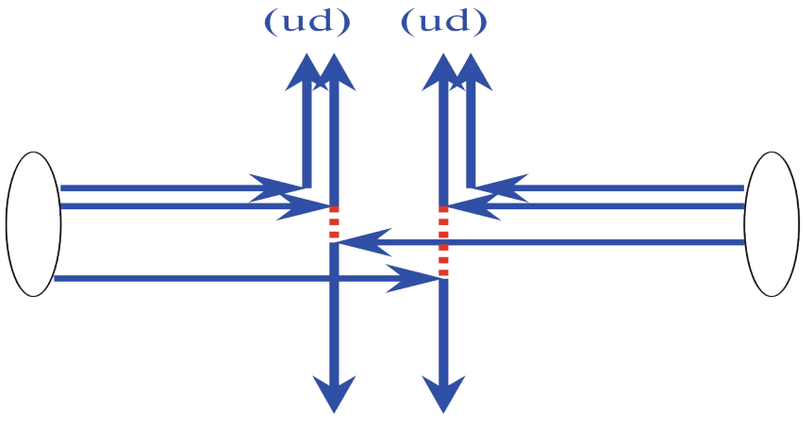

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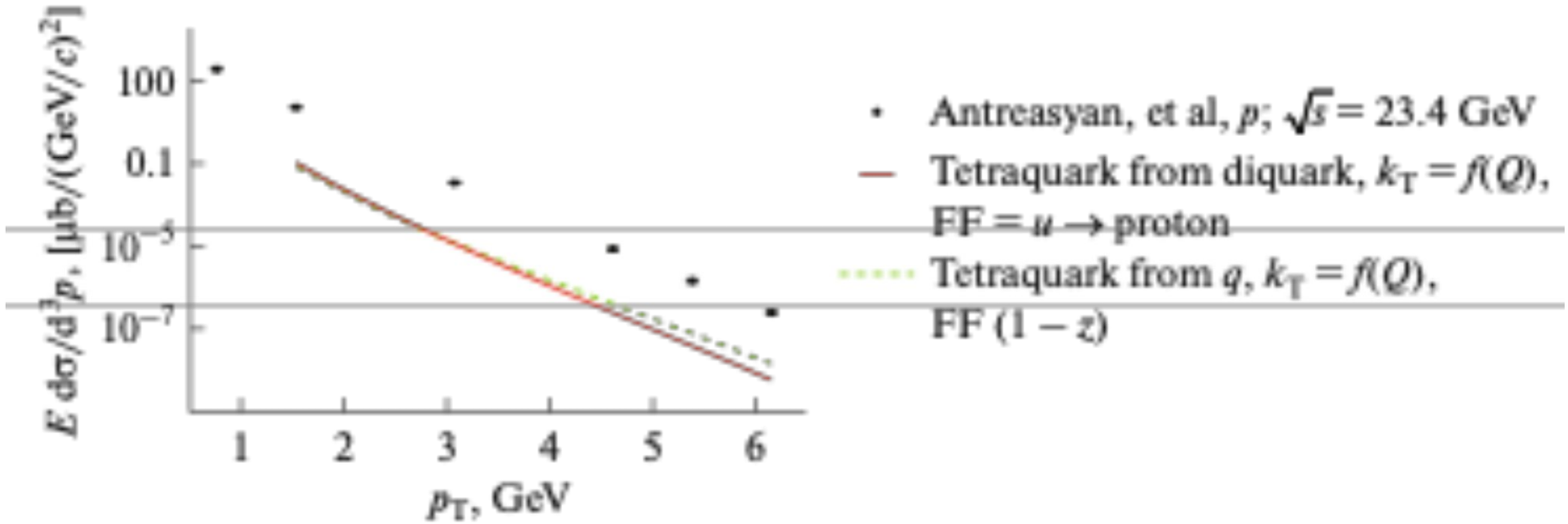
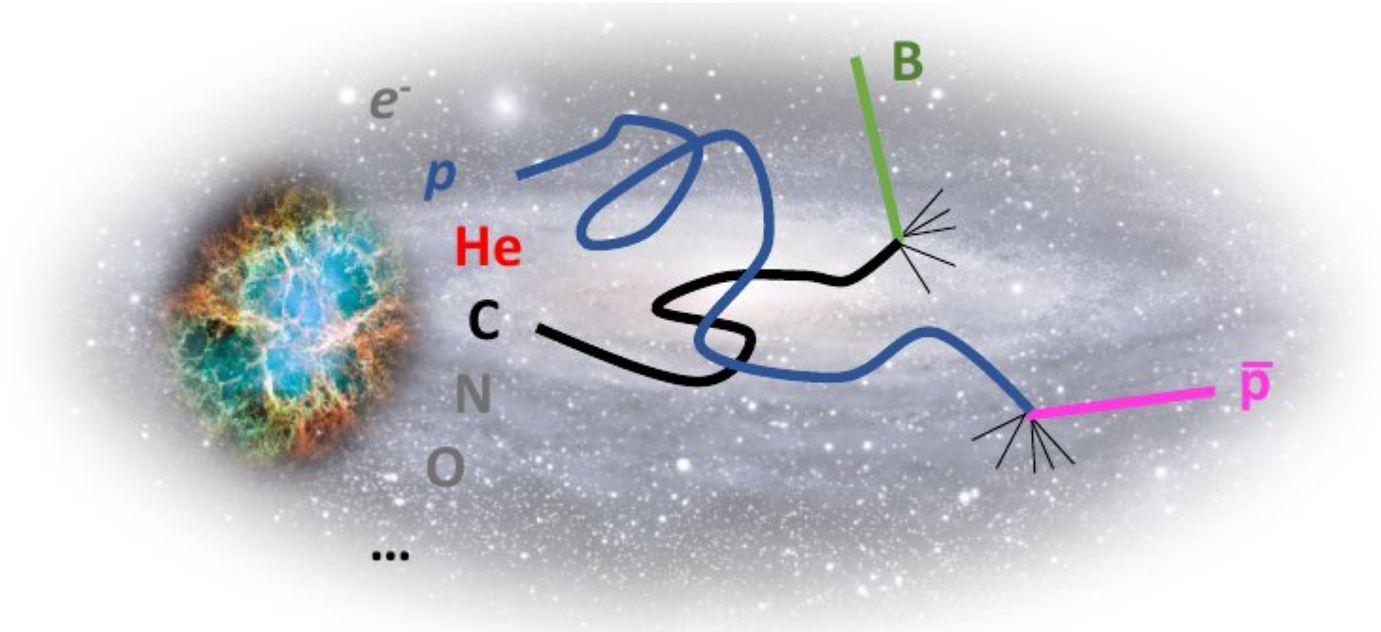


SPD Physics at the Stage-1: antiproton production



ASTROPHYSICS

AMS-02 in International Space Station

AMS-02 search for Dark Matter:
antiproton flux precision ~ 5%

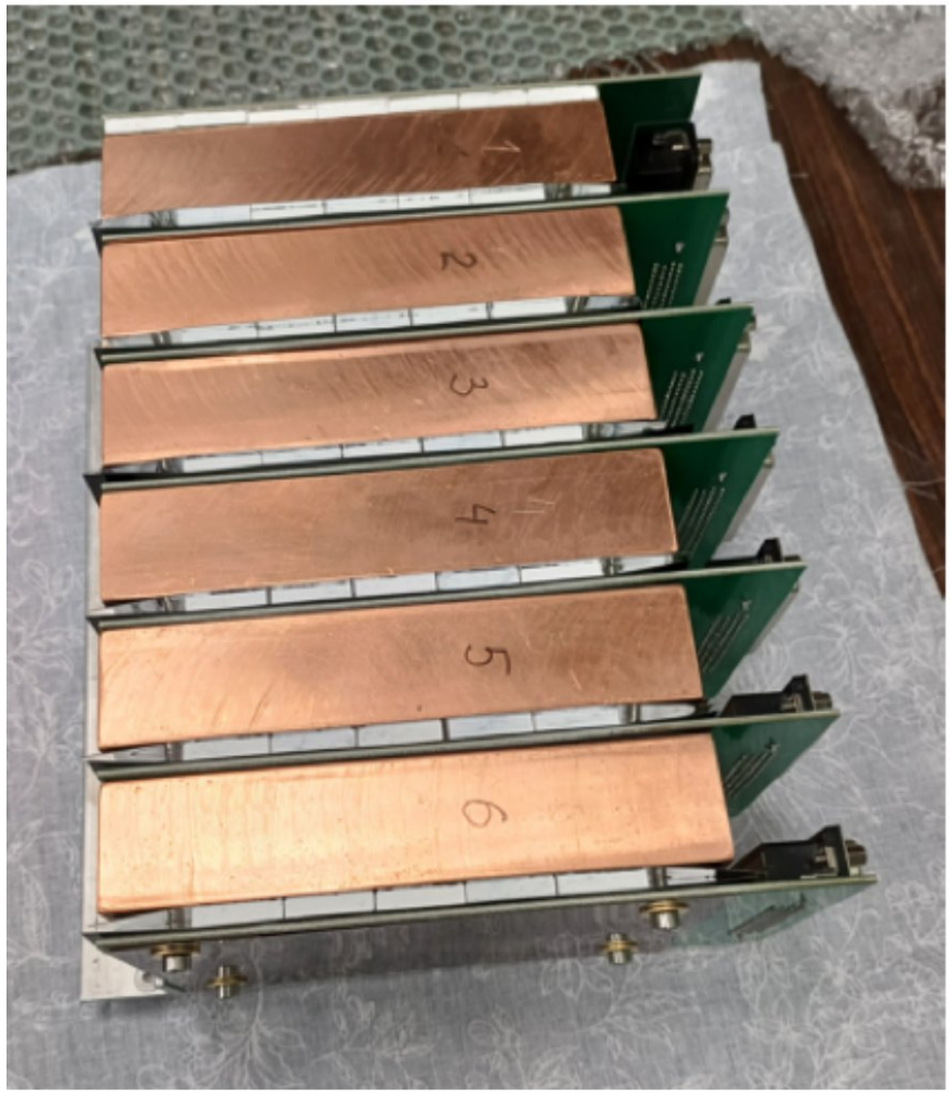
Contemporary high energy physics experiments
antiproton production ~ 25%

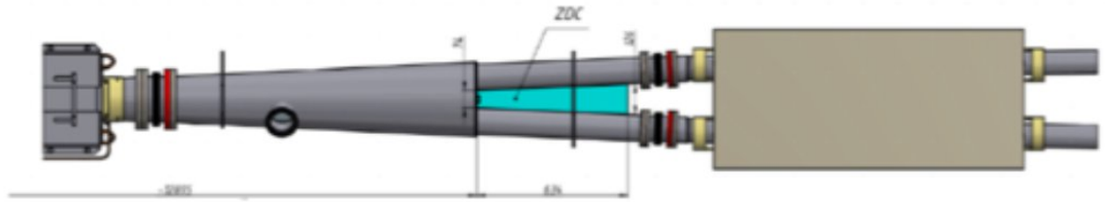
Precision antiproton production measurements needed:
energy range 5 GeV < ECM < 100 GeV with precision ~ 5%

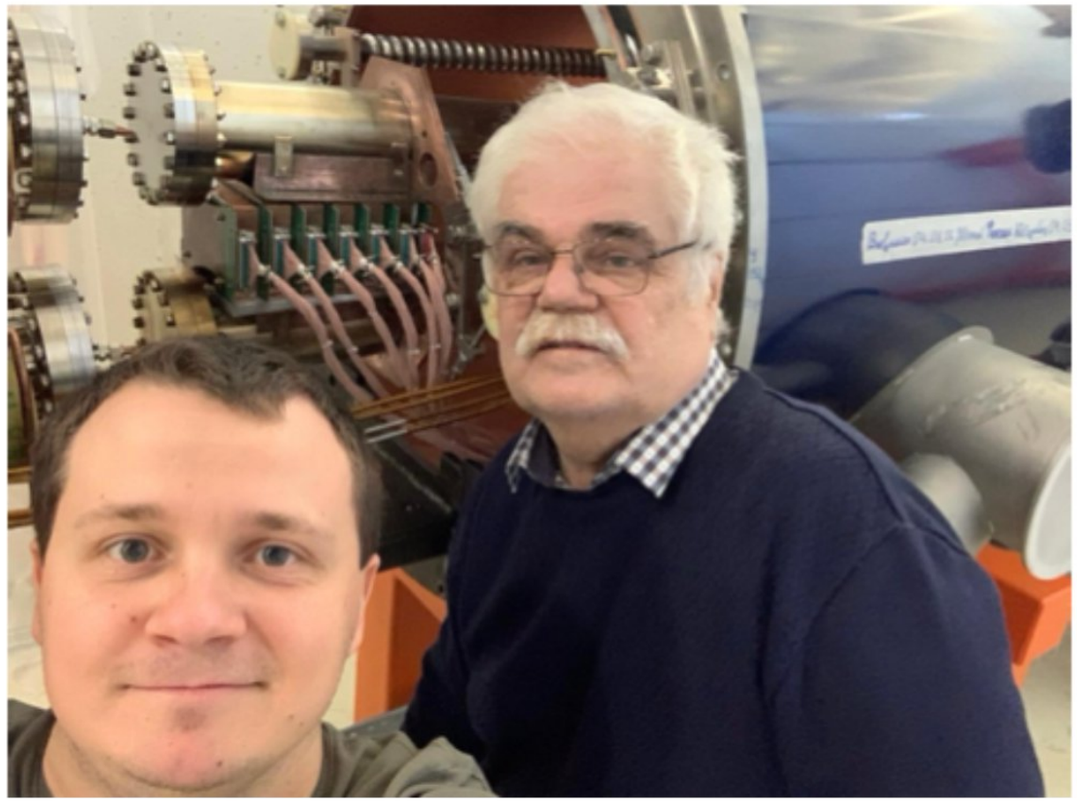
SPD now: main focus

- Load-bearing structure of the Detector & Yoke
- Superconducting magnet (INP, Novosibirsk)
- Engineering infrastructure & communications
- The 1st Stage detectors: Trackers, Muon (RS), BBC, ZDC, part of ECAL -> to manufacture
- The 2nd Stage detectors: ToF, FARICH, Vertex detector -> R&D
- DAQ and computing infrastructure
- The 1st Stage Physics program -> Updating
- SPD Interaction Point at NICA -> ZDC (and BBC) are installed

SPD Interaction Point: ZDC prototypes installed







SPD Interaction Point:

- The 1st ZDC and the 2nd ZDC prototypes are installed already

The First NICA Collider Data:
MPD Interaction Point
SPD Interaction Point

MPD Interaction Point:

- **The 1st Stage MPD**

SPD Interaction Point:

- **The 0th Stage SPD**
- **The ZDC and BBC prototypes**

Both MPD and SPD at the 0th Stage:
as soon as NICA in beam operation !

Fall 2026 (?)

New Physics beyond the Standard Model Searches at NICA

Proposal for New Physics Search at NICA
(with upgrade of the Nuclotron: longer straight sections):

- **CP-violation (Okun, Lee, Veltman et al.)**
  beyond the Standard Model searches
  by high angular momentum in non-central collisions

- **EDM of proton and deuteron**

- **Axion search**

....
N.N. Nikolaev et al., Yu.V. Senichev et al. (2022-2025)

SUMMARY

BM@N, MPD and SPD research programs:

► **Complementary studies extending probes to the important regions**

► **Wide physics program at the MPD and SPD:**
- **search for phase transition and critical energy point**
- **3D spin parton distribution functions of proton and deuteron**
- **search for exotic resonances (glueball, penta- and tetra- quarks), …**
- **multiquarks nuclear fluctons and few-nucleon correlations …**
- **…**
- **proposals of search for New Physics beyond the Standard Model**

► **The BM@N, MPD and SPD research programs will define the world level of the corresponding directions of high energy physics**

MPD and SPD at NICA collider:
dynamically developing and in a good shape!