SPIN PHYSICS DETECTOR PROJECT AT NICA

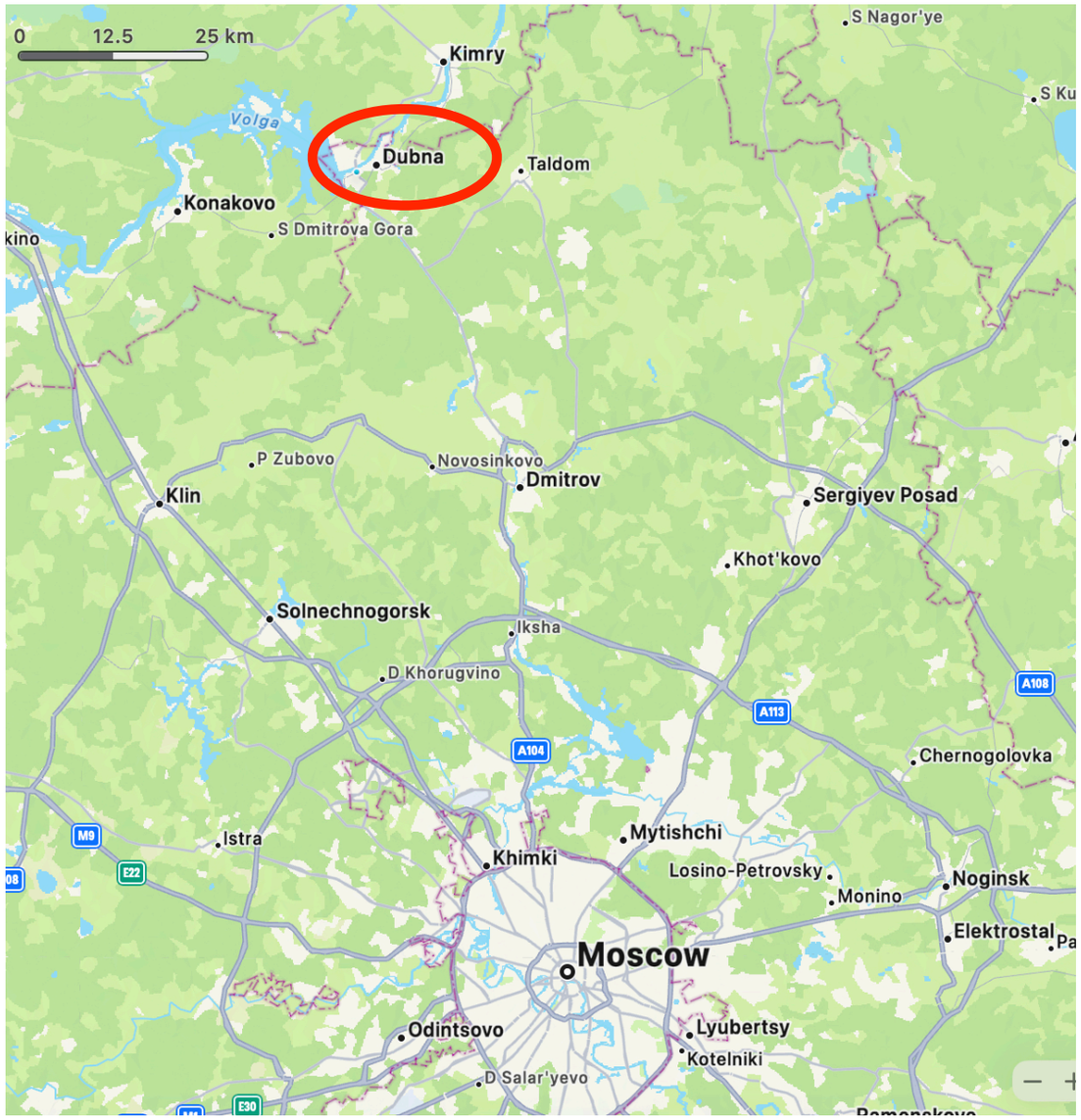
Alexey Guskov
JINR
avg@jinr.int

on behalf of the SPD Collaboration

30.10.2026

THE JOINT INSTITUTE FOR NUCLEAR RESEARCH, DUBNA, RUSSIA

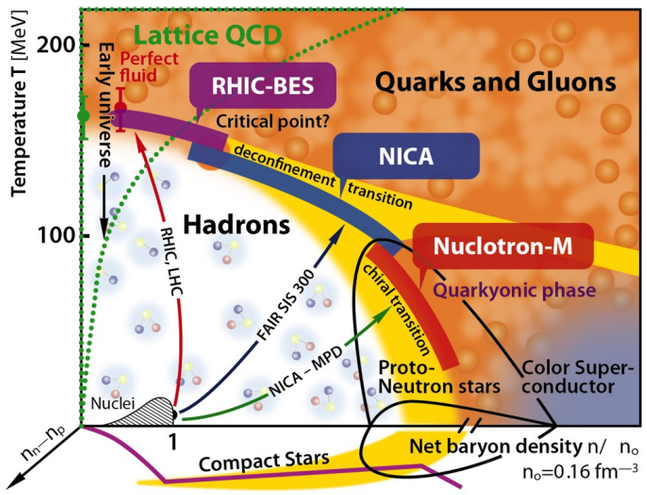




The Joint Institute for Nuclear Research is an international intergovernmental scientific research organization in the science city Dubna of the Moscow region (Russia)

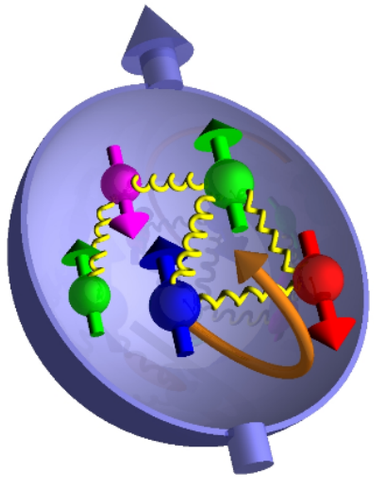
NICA facility at JINR

NICA (Nuclotron-based Ion Collider fAcility)



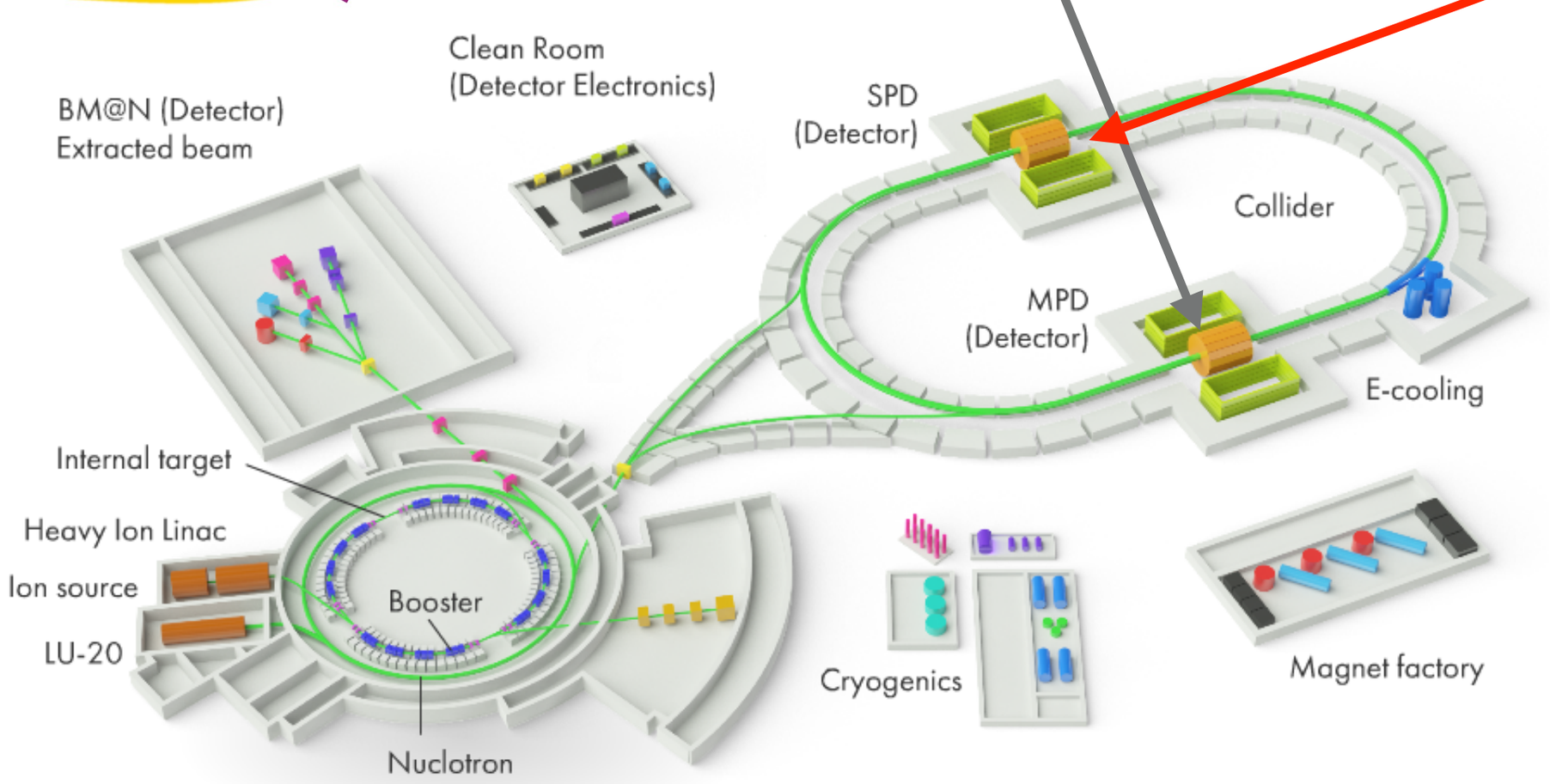
Stage 1

Hot hadronic matter in extremal conditions with heavy-ion beams



Stage 2

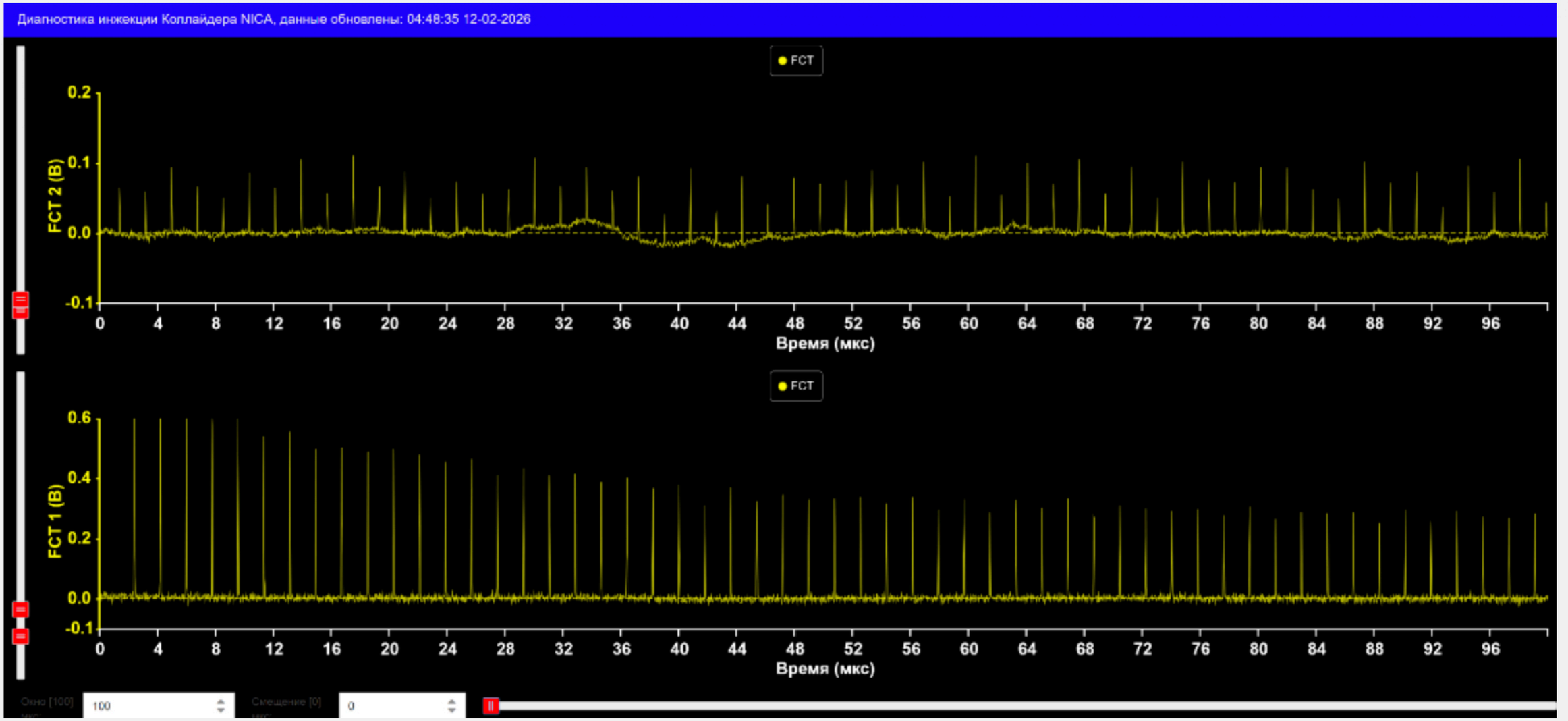
Proton and deuteron spin structure with polarized beams



NICA landscape

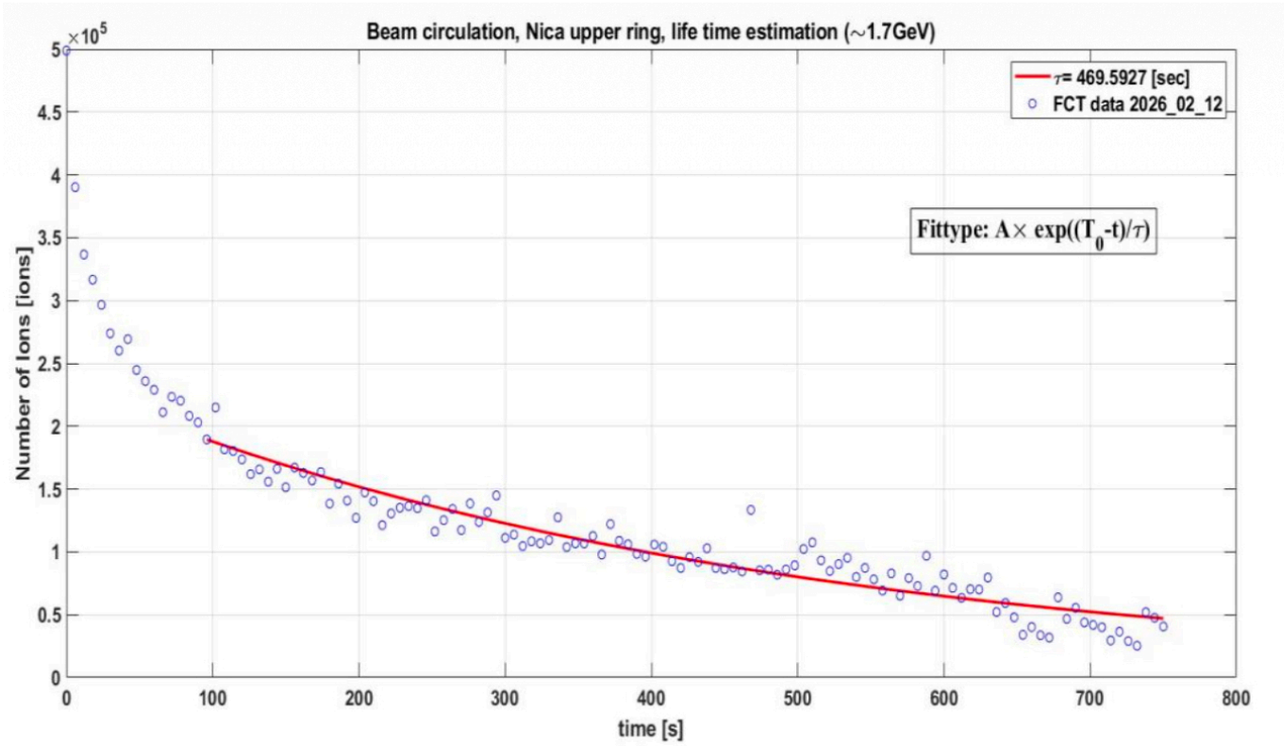


First beams in the NICA ring

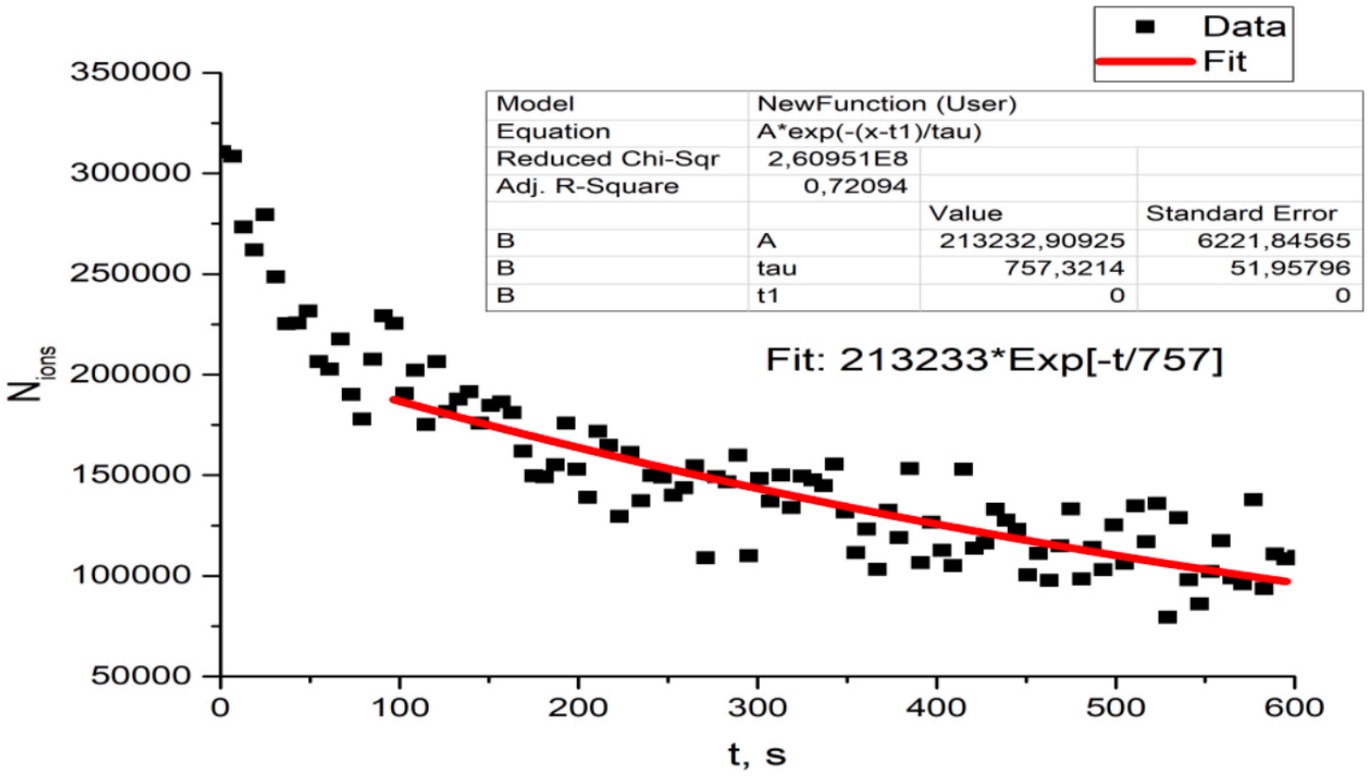


12.2.2026: 1.76 GeV/n Xe beams circulation in both rings

First beams in the NICA ring



Up ring: **459** *s*



Down ring: **757** *s*

First beams in the NICA ring



New run is ongoing. First heavy-ion collisions are expected this winter

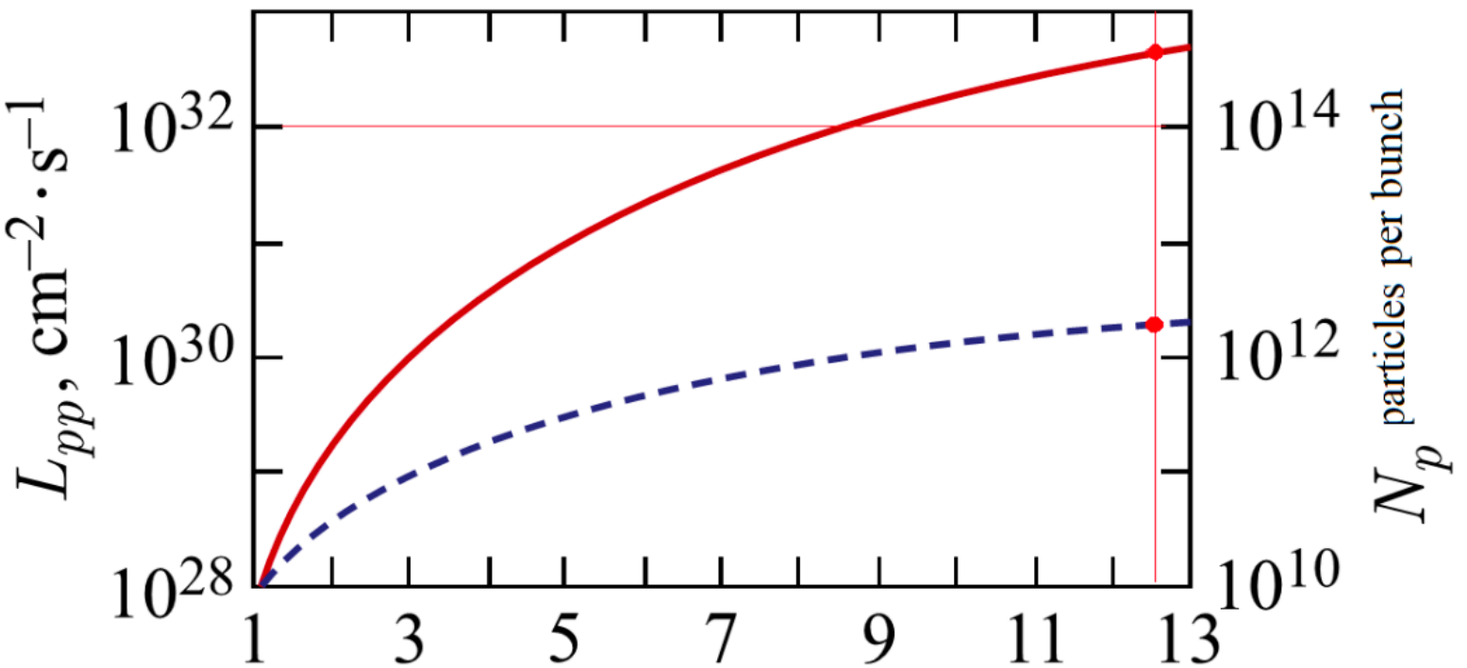
NICA for spin physics

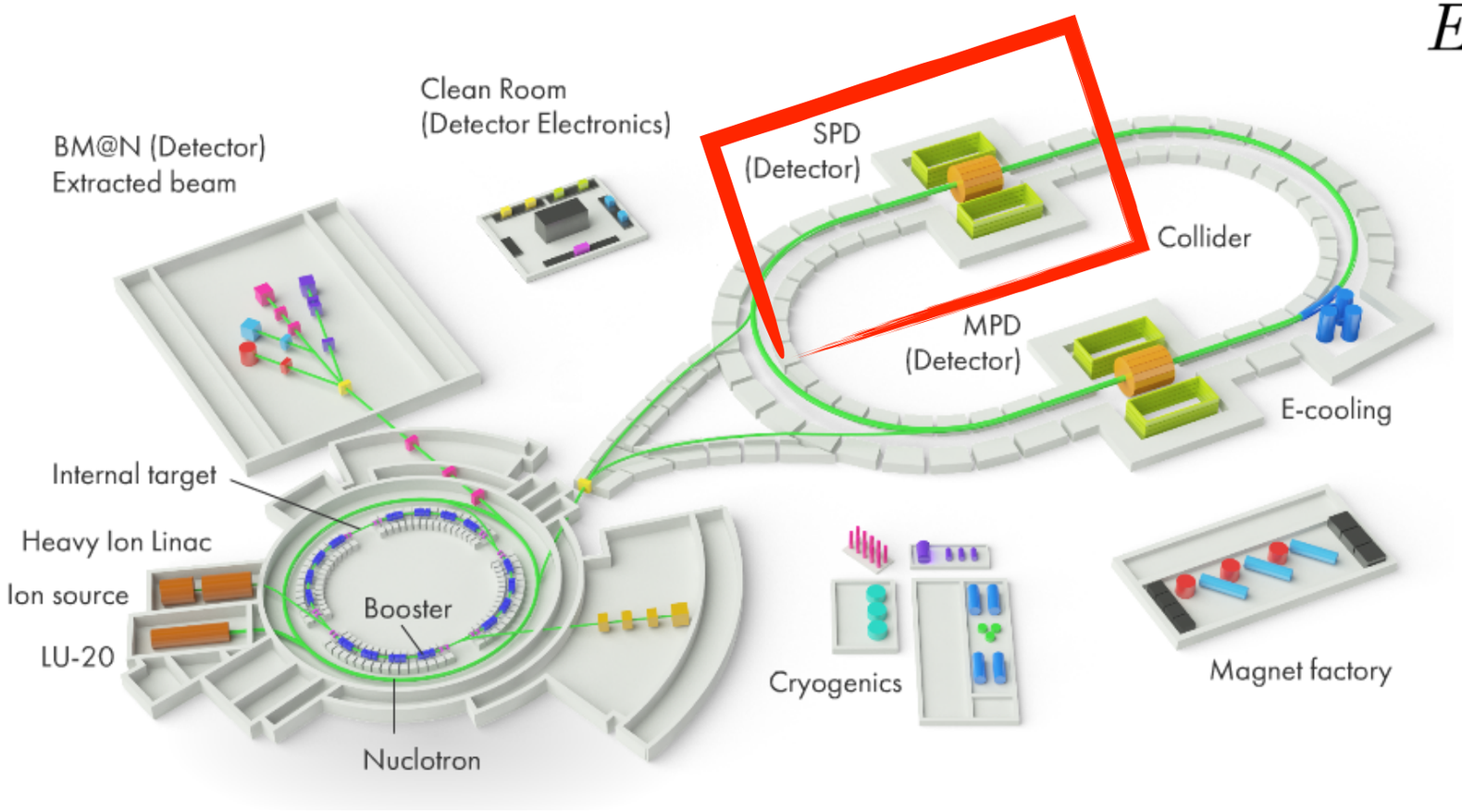
Polarized proton and deuteron beams:

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

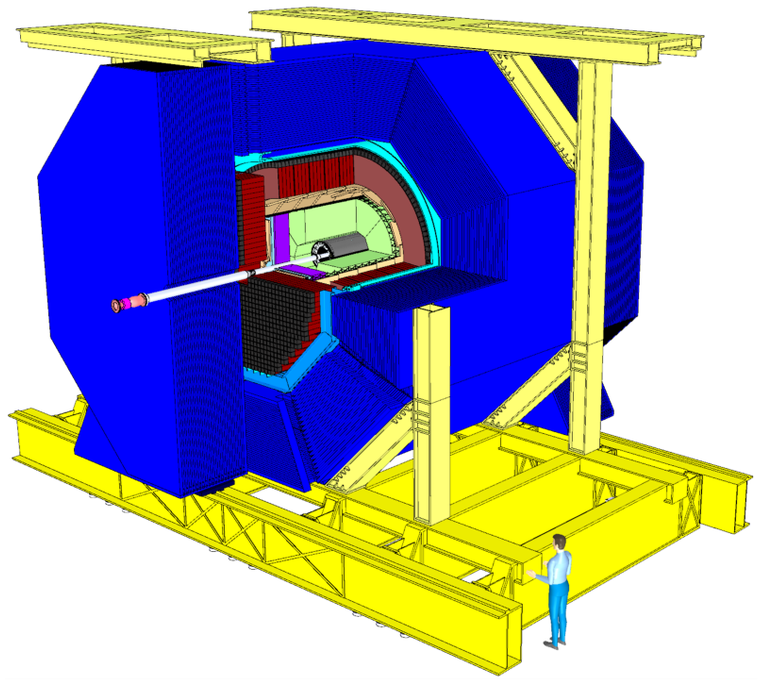
U, L, T |P|>70%

Polarized ^{3}He beams are also possible





Spin Physics Detector



Polarized beams at NICA

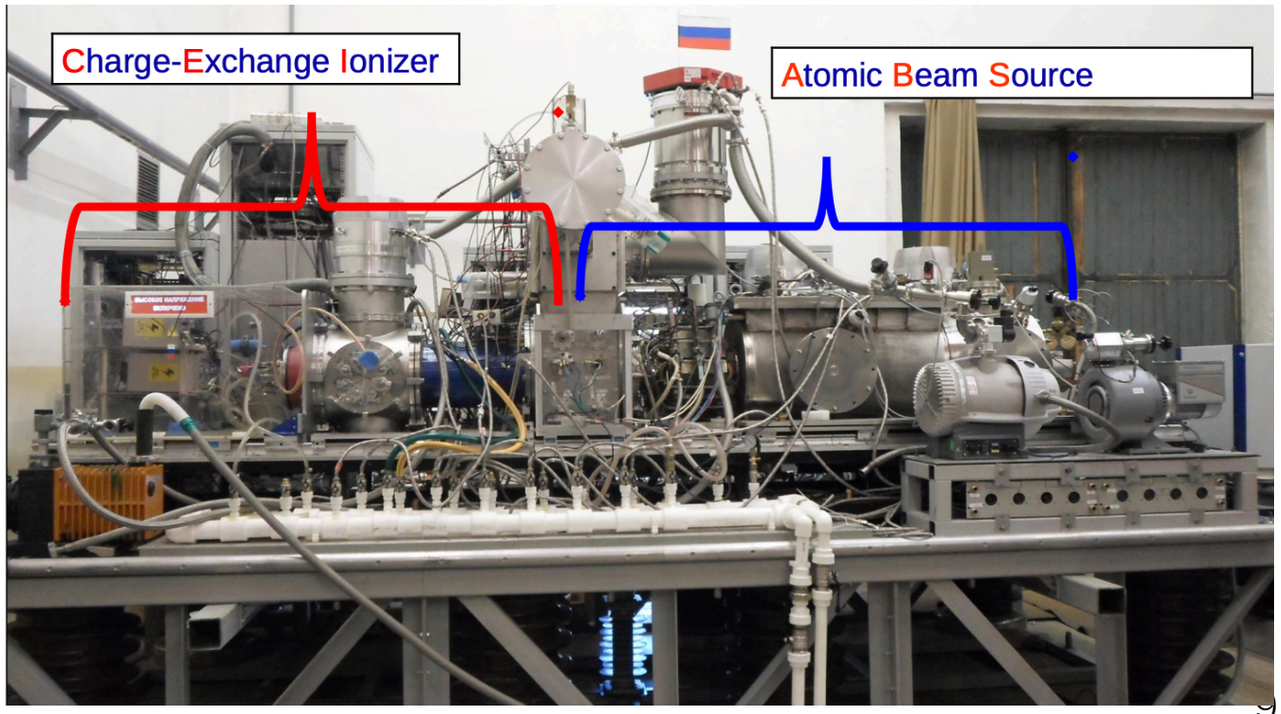
d↑- was accelerated in 1986 (Synchrophasotron) and 2002 (Nuclotron). It is quite simple procedure: there is just 1 depolarizing spin resonance at 5.6 GeV.

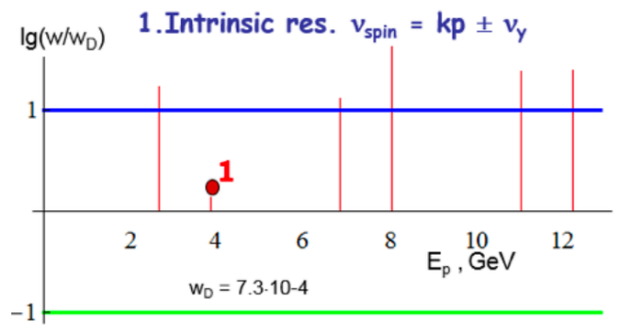
p↑- was first obtained only in 2017.

Source of Polarized Ions:

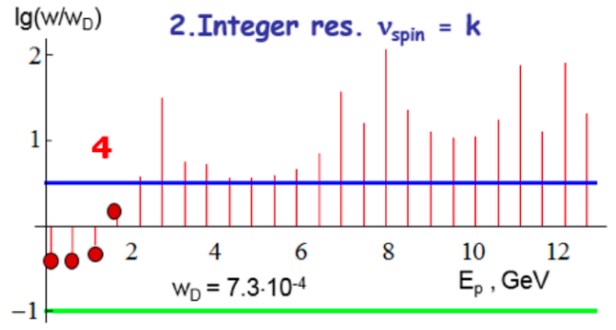
$$H^0 \uparrow + D^+ \rightarrow H^+ \uparrow + D^0$$

$$D^0 \uparrow + H^+ \rightarrow D^+ \uparrow + H^0$$

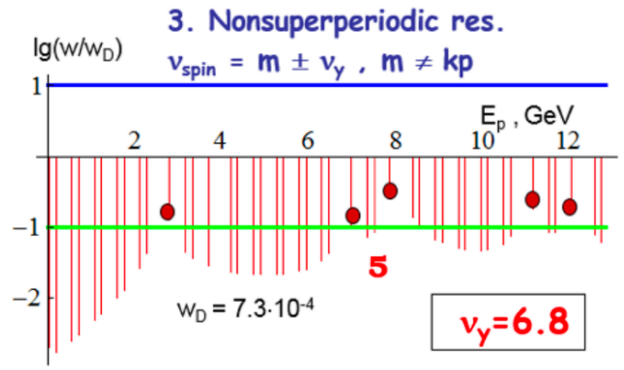


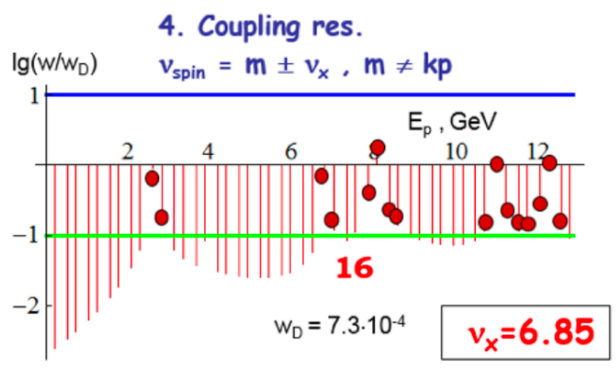


(a)



(b)





- Longitudinal polarization in the IP can be supported at the integer spin-resonances
  - For protons: E_{kin}=(0.108+0.523·n) [GeV]
  - For deuterons: E_{kin}=(5.62+6.56·n) [GeV/u]

- Transverse polarization at any energies

Spin Physics Detector project

Mid-2000s

Idea of the experiment

2014

Letter of Intent

2021

Physics programme update

Foundation of the SPD Collaboration

Conceptual Design Report

2024 2025

Technical Design Report

Start of the detector construction

~2032

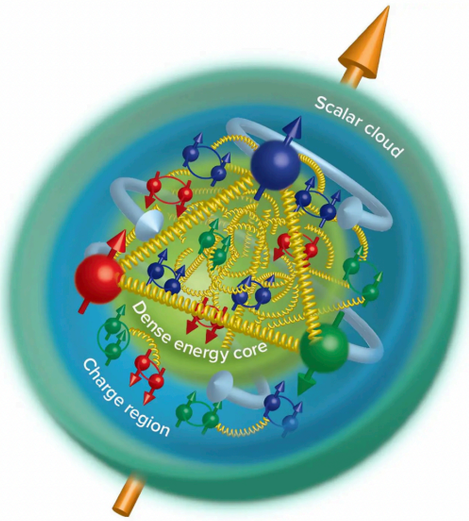
1-st phase measurements

~2035

2-nd phase measurements

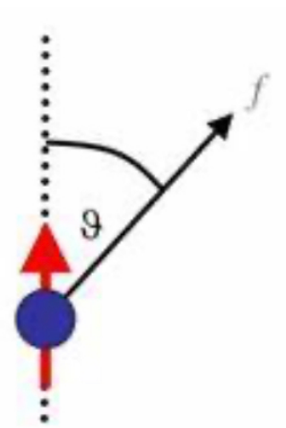
SPD NICA

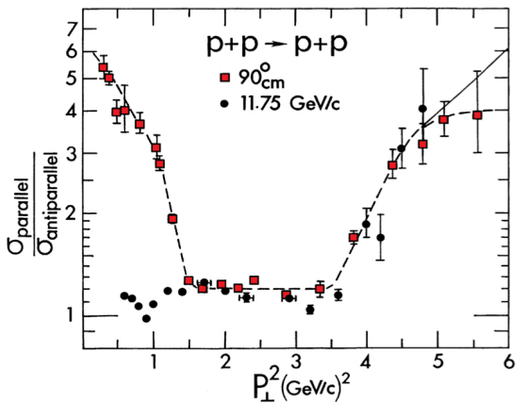
Physics @ SPD



- *Gluon polarized PDFs (TMDs and helicity)*
- *Quark polarized PDFs*
- *Deuteron tensor PDFs*

- *Spin effects in hadroproduction*
- *Polarization of hyperons and charmonia*
- *Spin correlations*





- *Other spin-dependent phenomena*

- *Unpolarized physics*

SPD gluon physics programme

Contents lists available at ScienceDirect

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp



Review

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

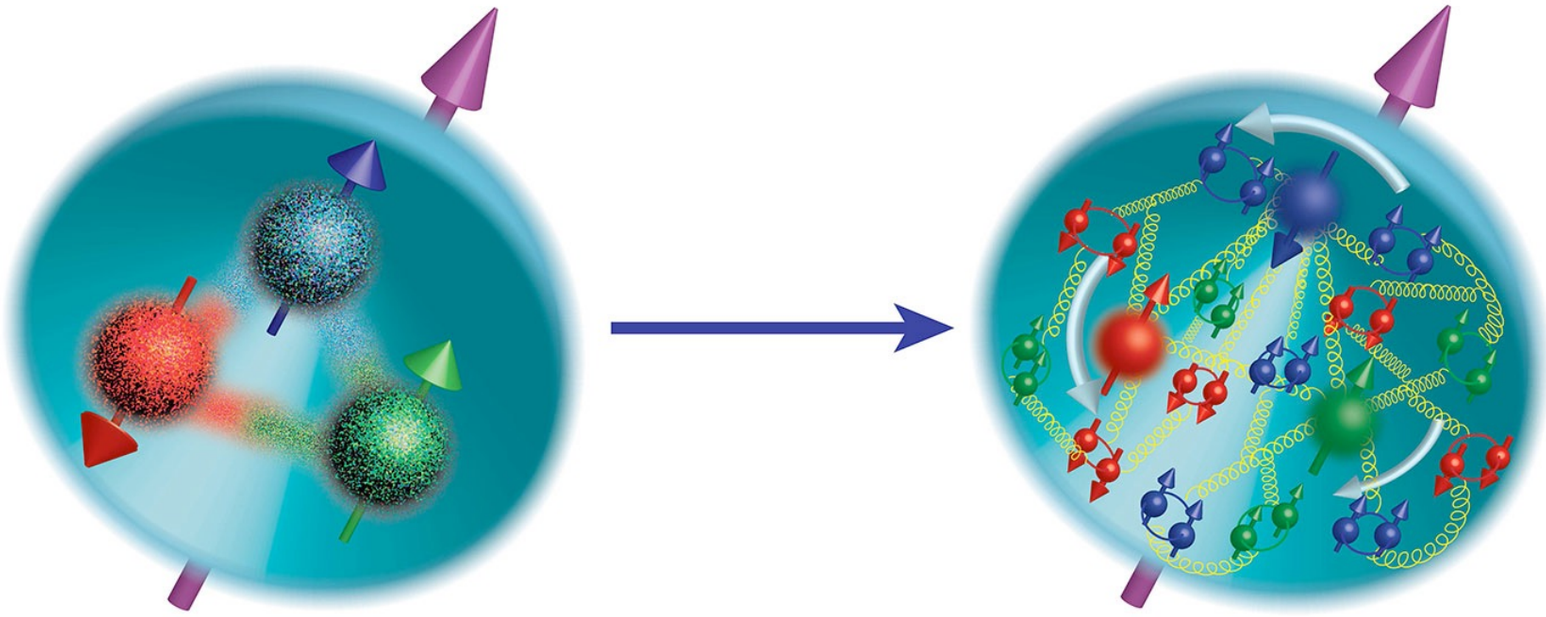
A. Arbuzov [a], A. Bacchetta [b,c], M. Butenschoen [d], F.G. Celiberto [b,c,e,f], U. D'Alesio [g,h], M. Deka [a], I. Denisenko [a], M.G. Echevarria [i], A. Efremov [a], N.Ya. Ivanov [a,j], A. Guskov [a,k,*], A. Karpishkov [l,a], Ya. Klopot [a,m], B.A. Kniehl [d], A. Kotzinian [j,o], S. Kumano [p], J.P.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

[a] Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia
[b] Dipartimento di Fisica, Università di Pavia, via Bassi 6, I-27100 Pavia, Italy
[c] INFN Sezione di Pavia, via Bassi 6, I-27100 Pavia, Italy
[d] II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany
[e] European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), I-38123 Villazzano, Trento, Italy
[f] Fondazione Bruno Kessler (FBK), I-38123 Povo, Trento, Italy
[g] Dipartimento di Fisica, Università di Cagliari, I-09042 Monserrato, Italy
[h] INFN Sezione di Cagliari, I-09042 Monserrato, Italy

Prog.Part.Nucl.Phys. 119 (2021) 103858

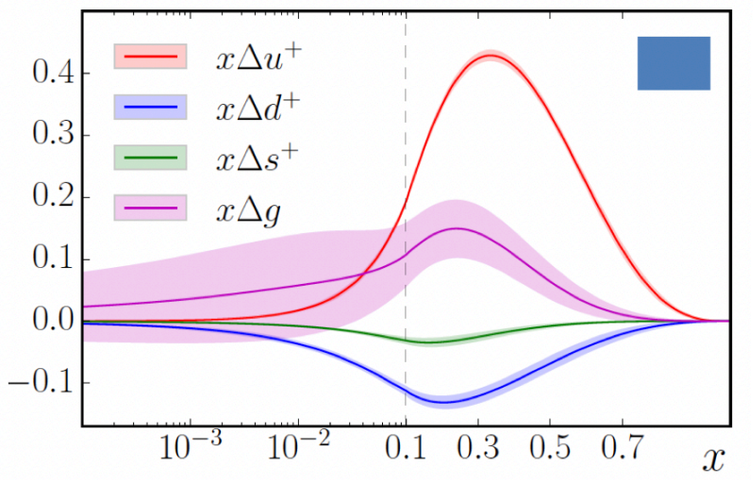
arXiv:2011.15005

Proton spin crisis

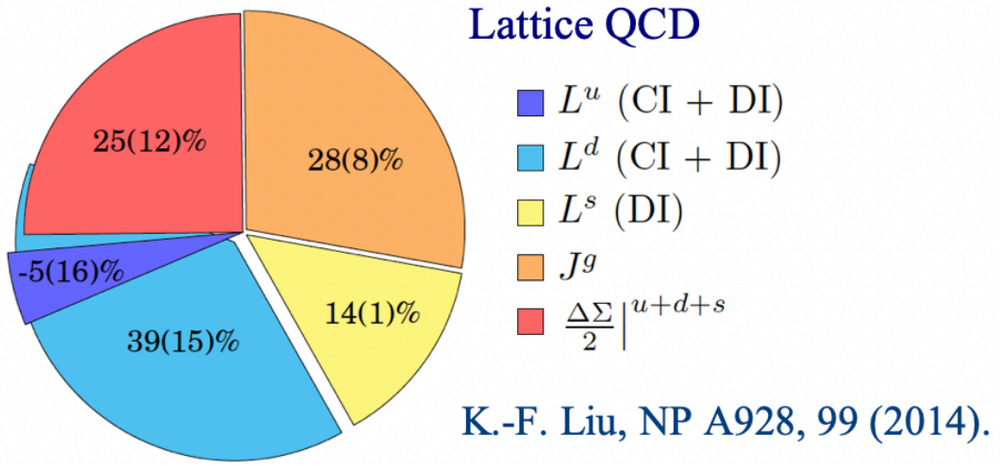


$$J = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

~30% ~10-20% ? ?



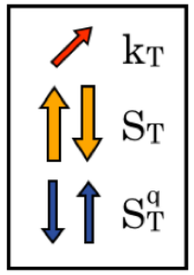
JAM Collaboration, PRD (2016).



K.-F. Liu, NP A928, 99 (2014).

No chance to disentangle proton spin puzzle without understanding its 3D structure!

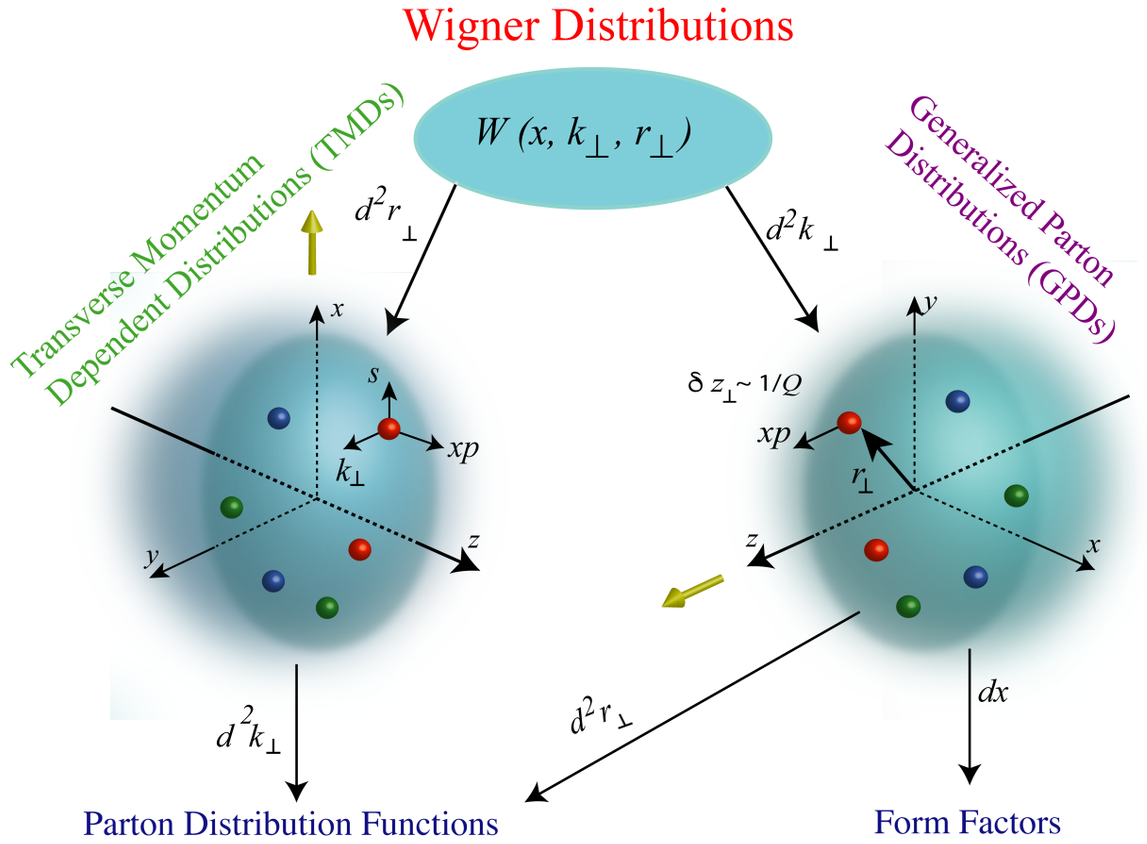
Proton in 3D: TMDs and GPDs



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

TMD PDFs



Partonic structure of proton

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

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

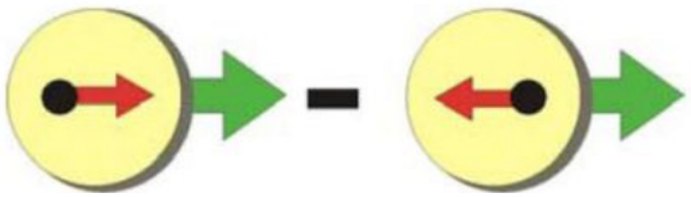
Unpolarized gluons in proton at high x:



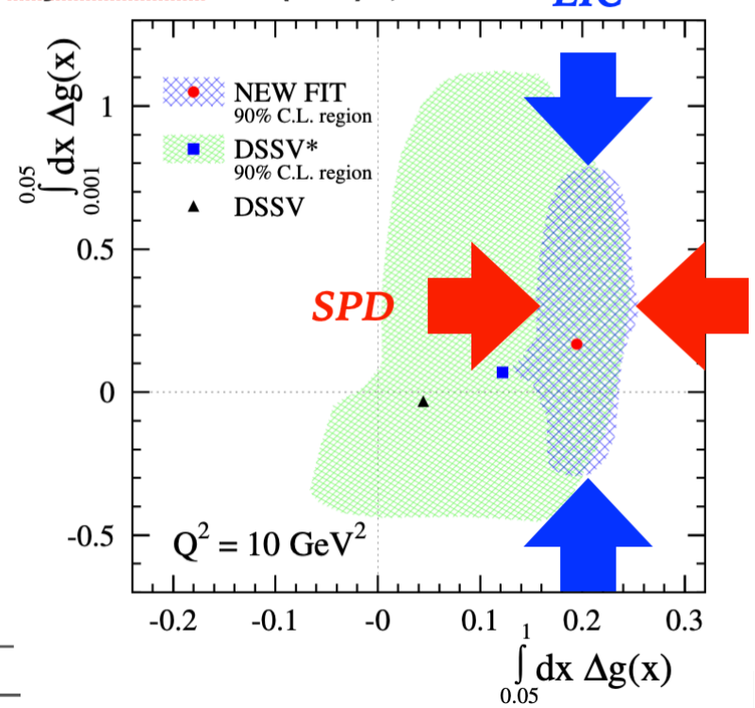
Spin crisis:

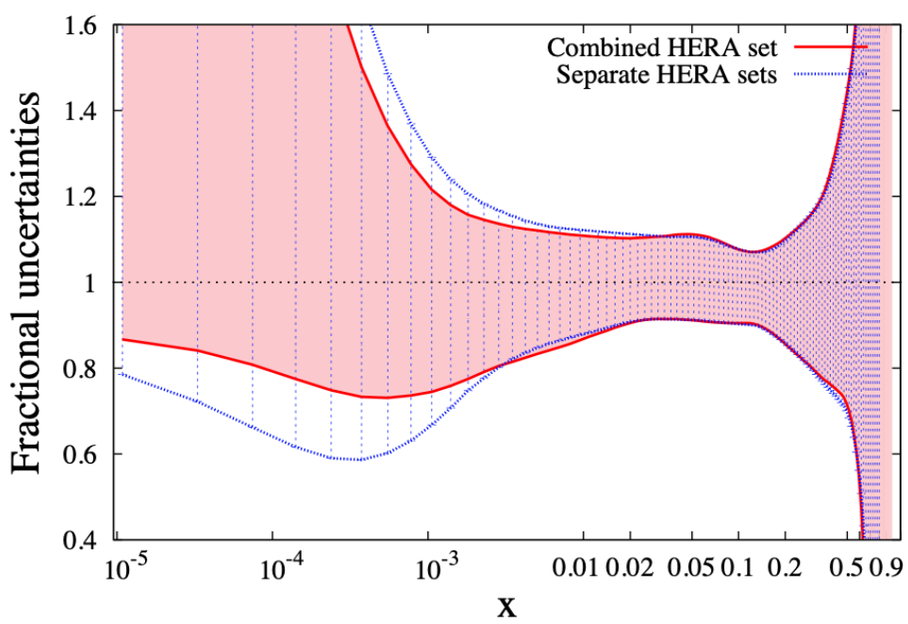
Gluon helicity



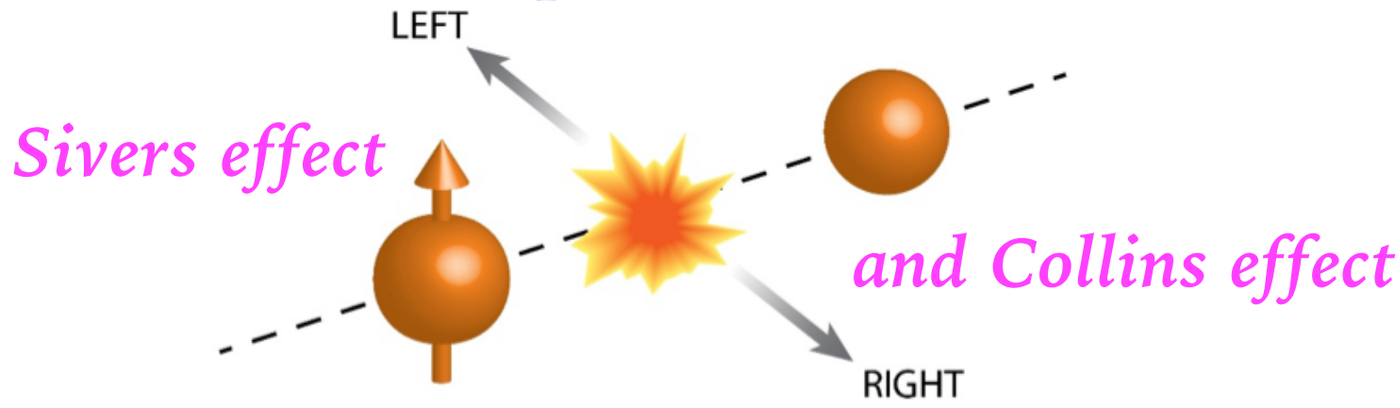


Phys.Rev.Lett. 113 (2014) 1, 012001 *EIC*





Gluon and quark TMD PDFs:



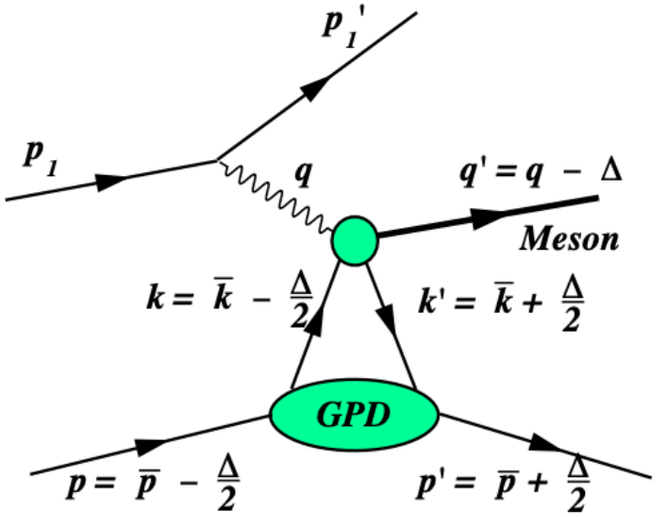
Sivers effect

and Collins effect

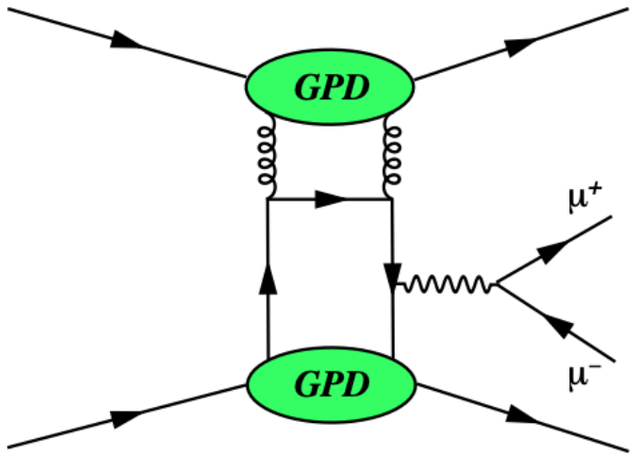
Spin-dependent fragmentation functions

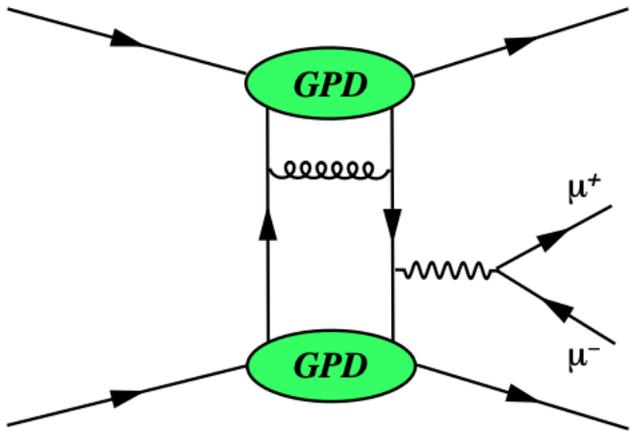
GPDs at SPD

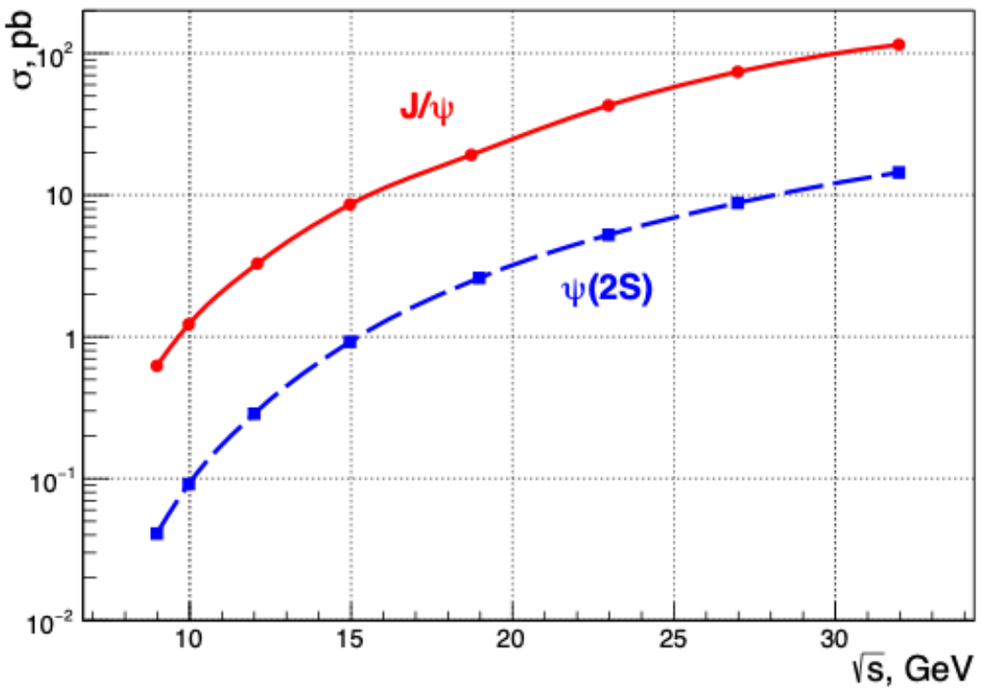
GPDs is not a priority goal at SPD but potentially they could be accessed:



Exclusive Drell-Yan



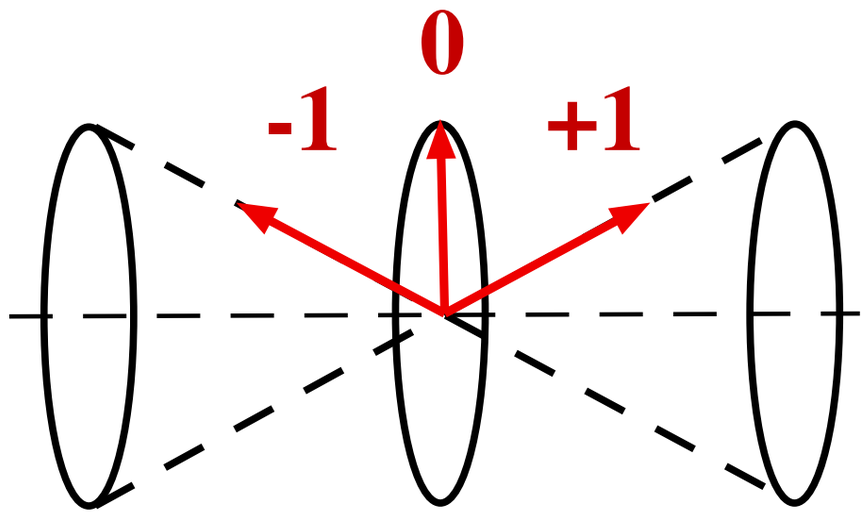




$$d\sigma/dQ^2 \sim 5\ pb/(GeV/c)^2$$
$$at\ \sqrt{s} = 24\ GeV\ and\ Q^2 = 5\ (GeV/c)^2$$

Deuteron

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



Nonbaryonic content of deuteron:

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

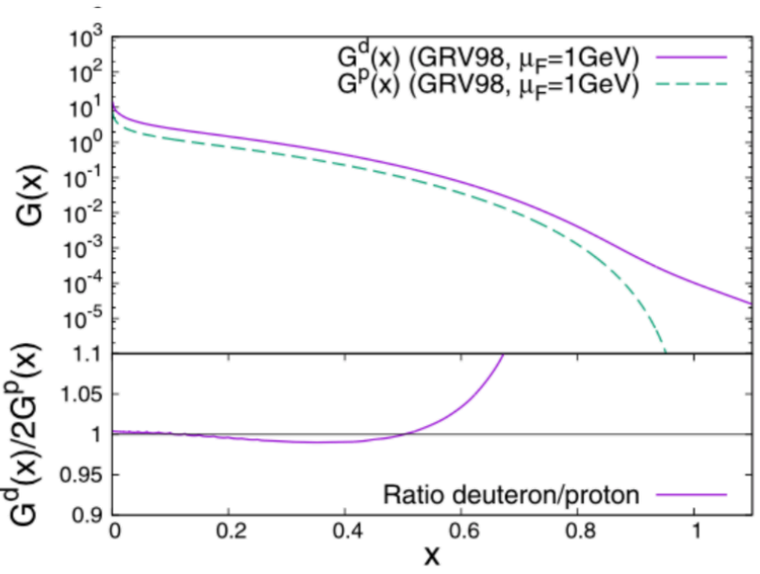
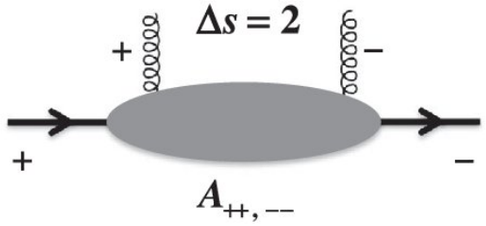
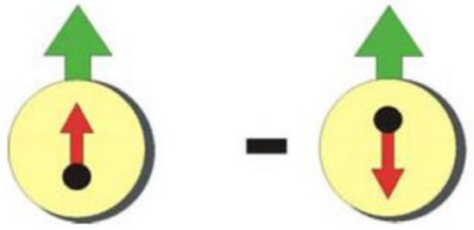


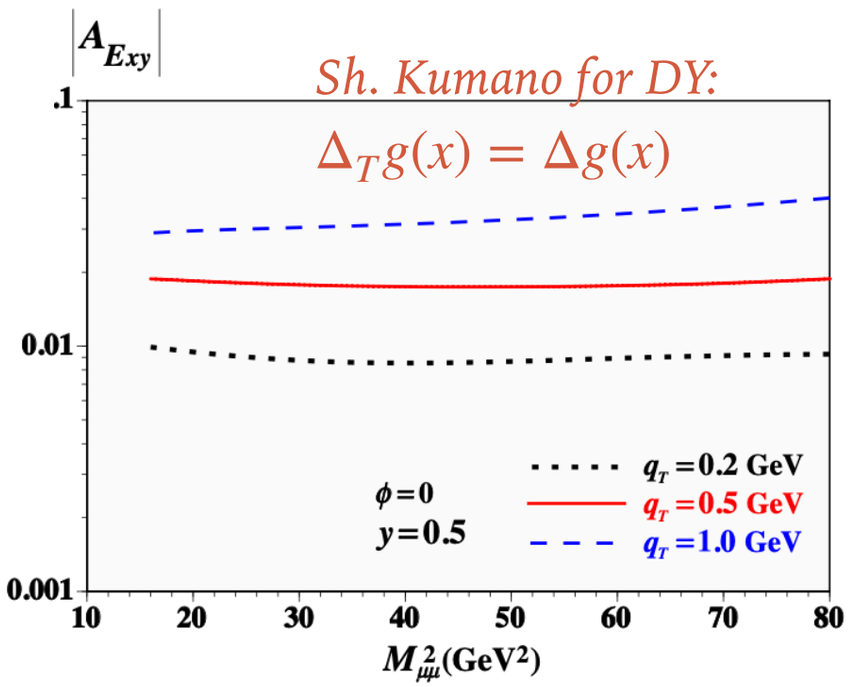
Fig. 6. Gluon PDF in the deuteron and in the nucleon.

Unpolarized gluons at high x:

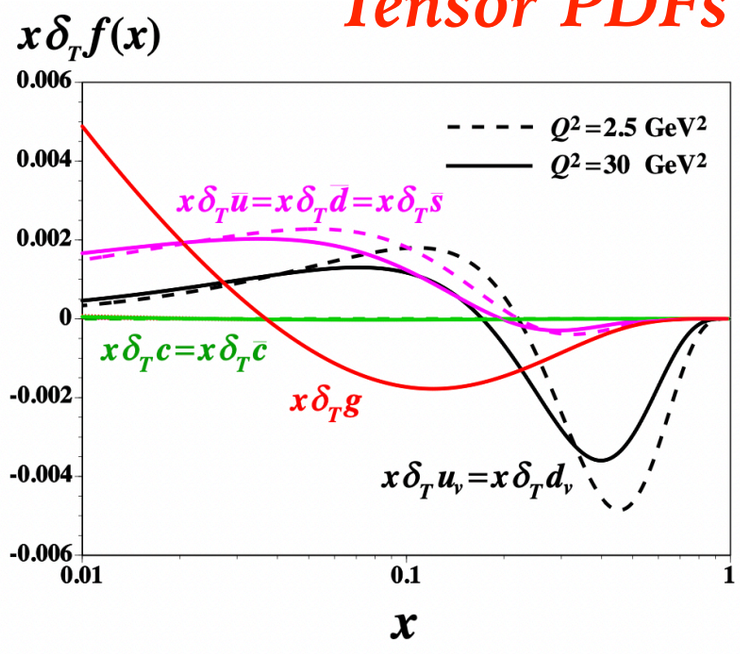
Gluon transversity





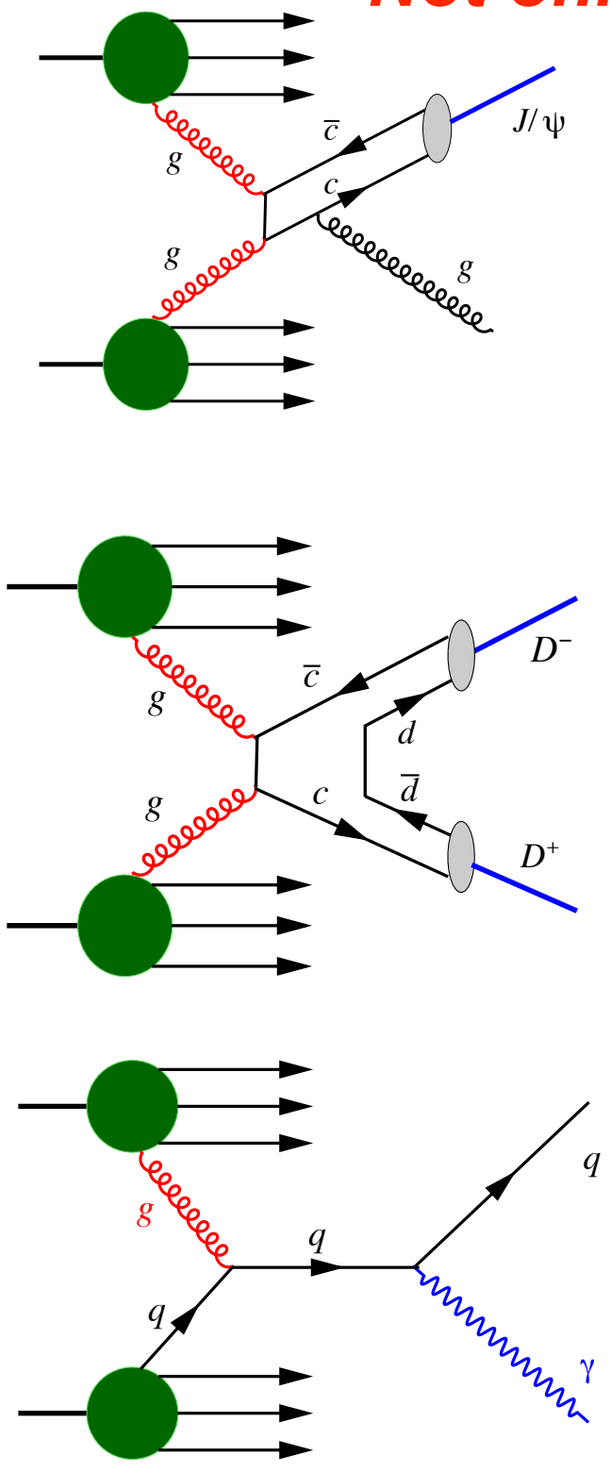


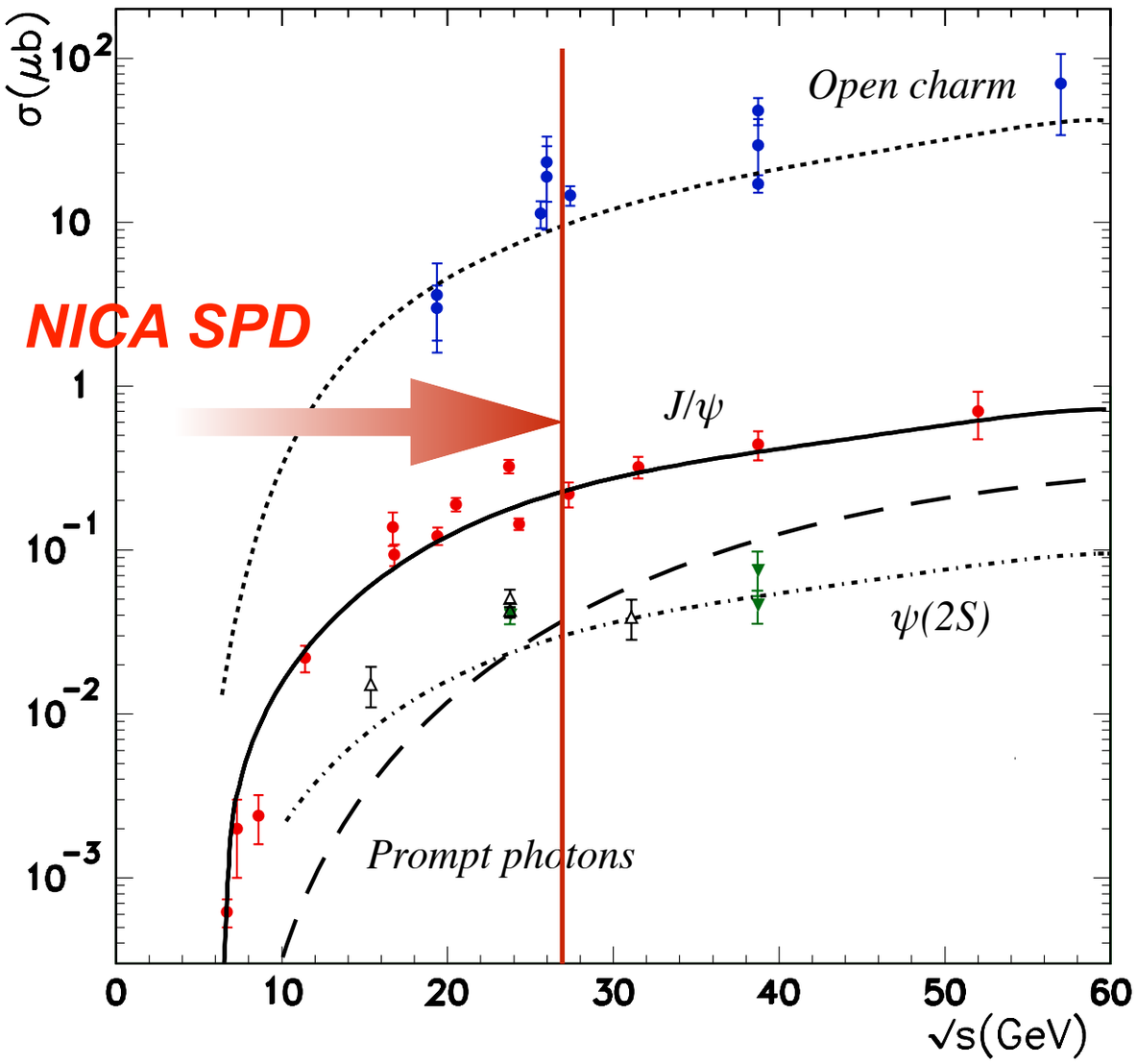
Tensor PDFs



SPD golden probes

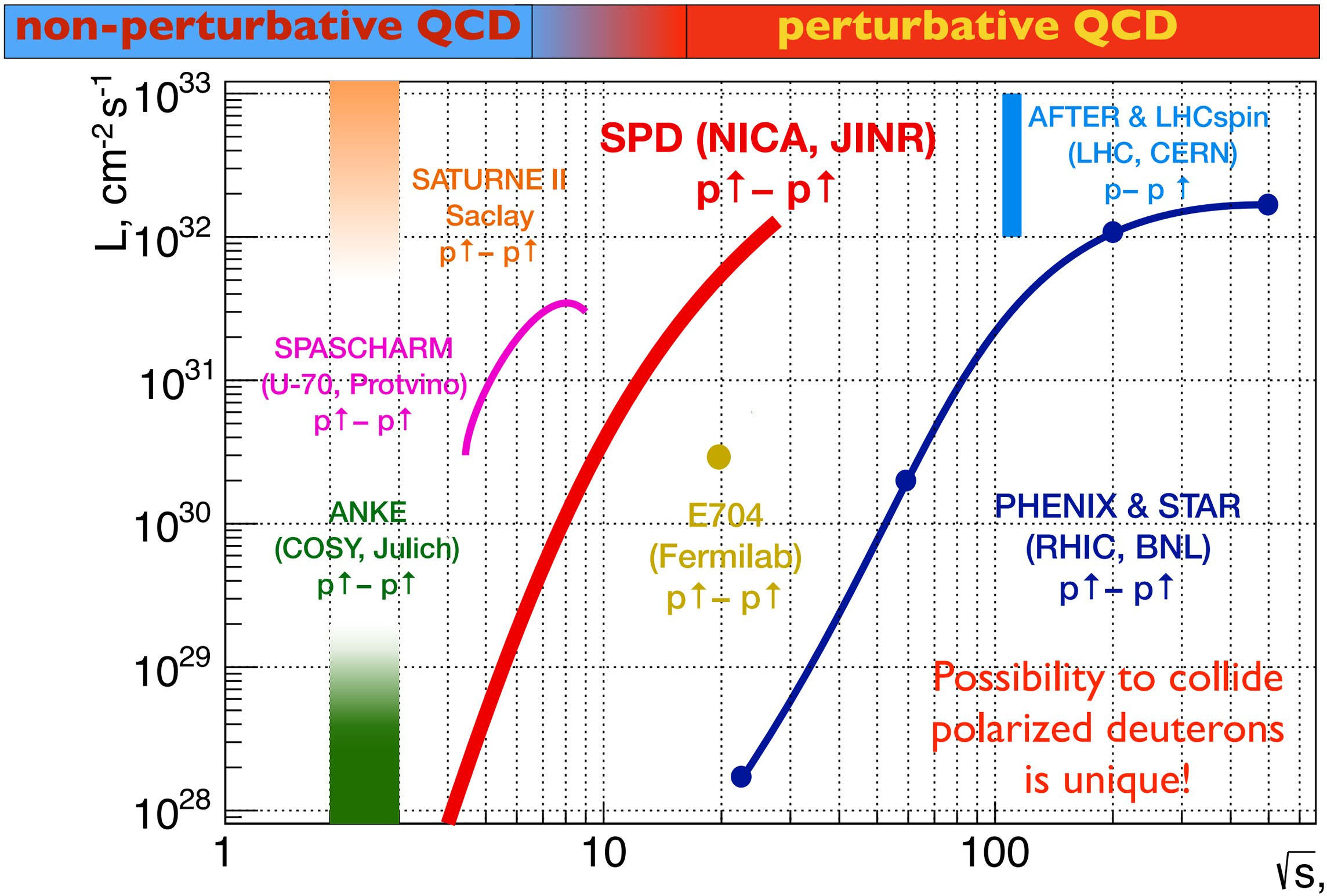
Not only J/ψ!



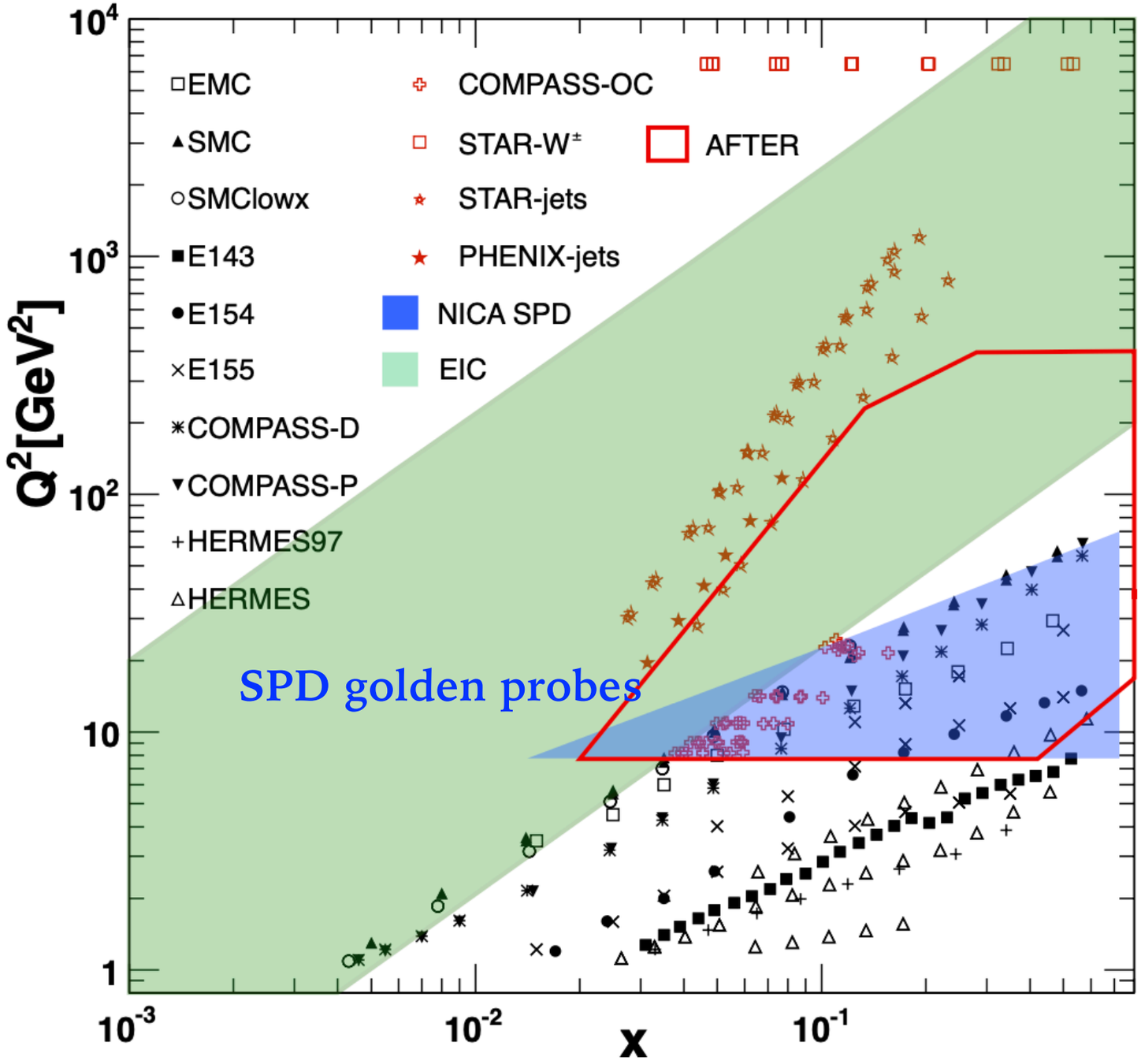


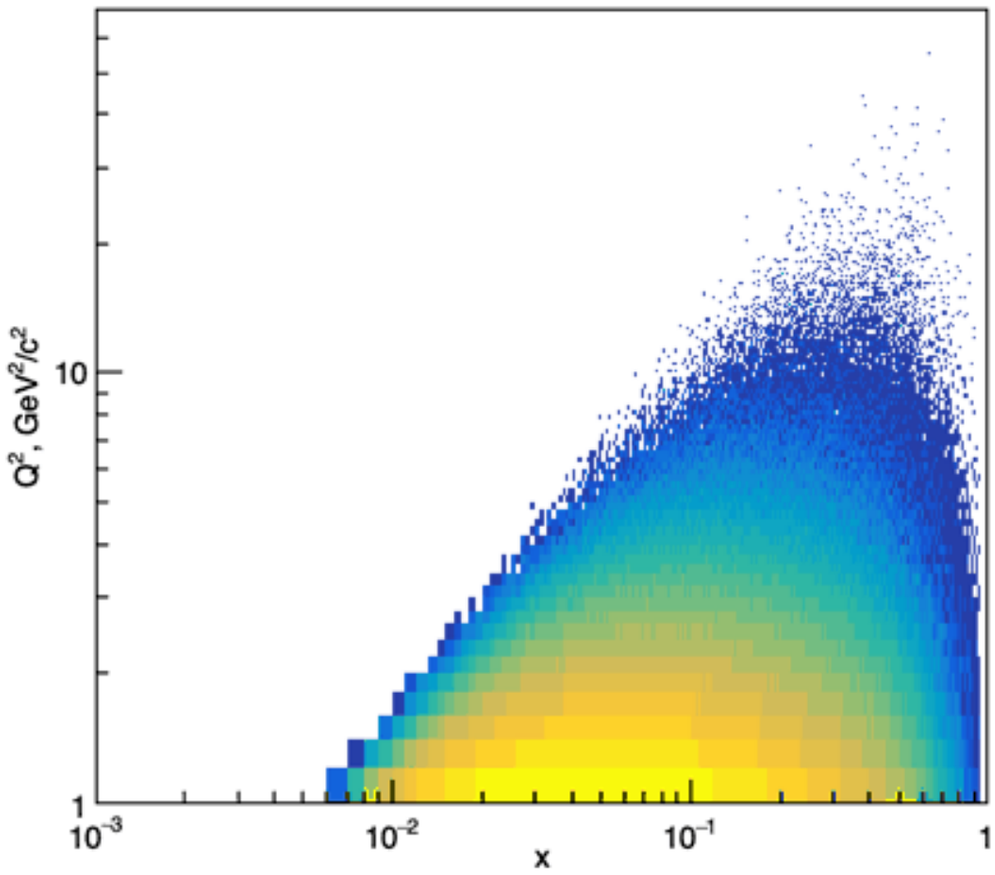
These golden probes define the layout of the SPD experimental setup.

SPD and other polarized pp exps



SPD and others

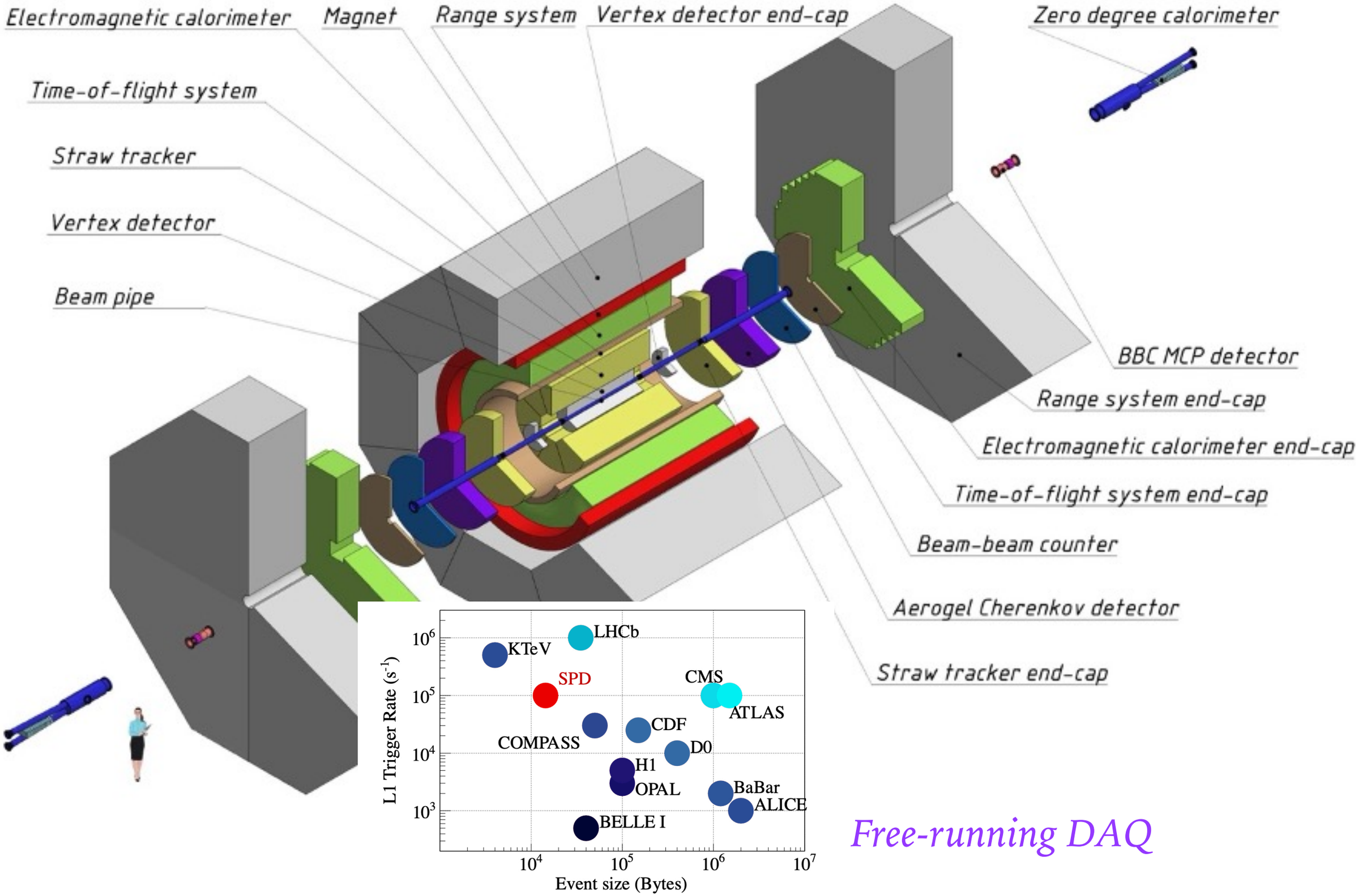




$Q^2 = 1\ GeV^2/c^2, < x > = 0.16$

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

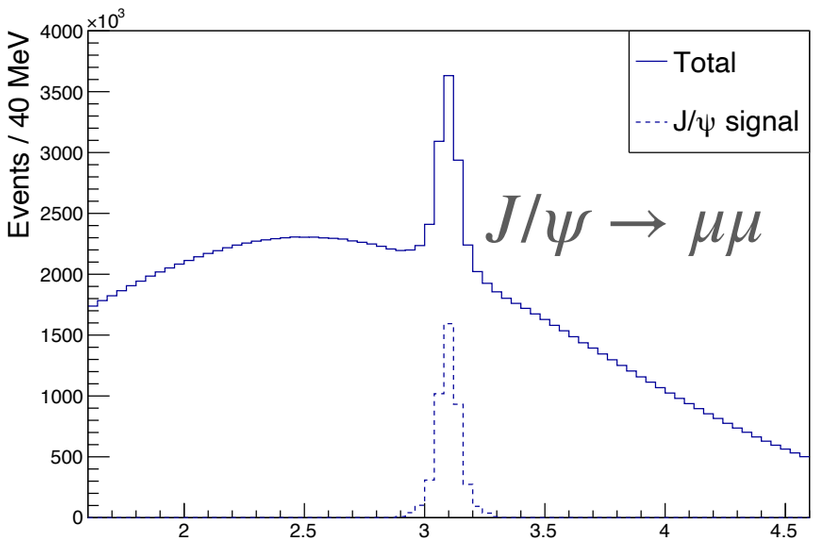
SPD full setup

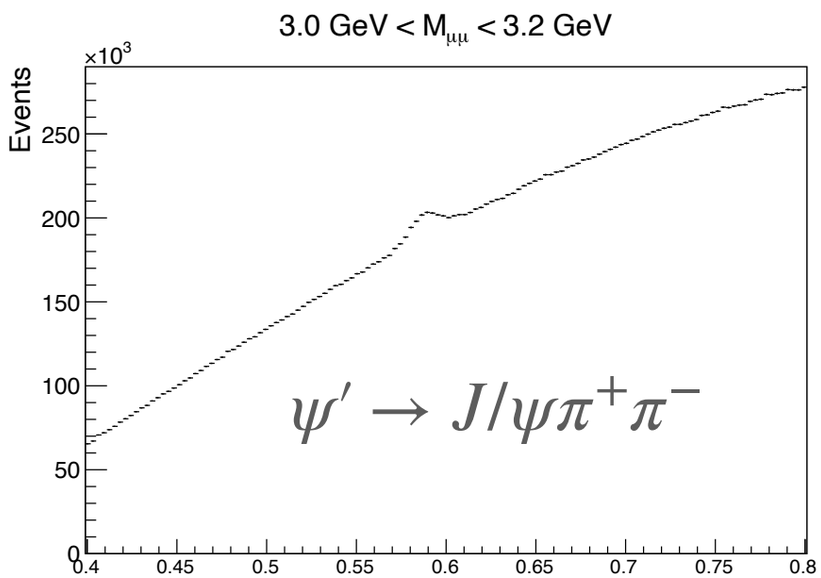


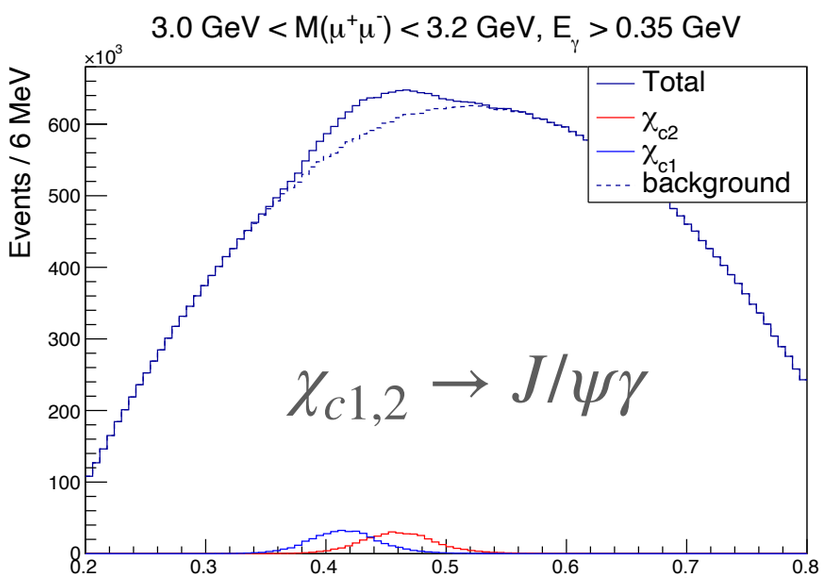
Free-running DAQ

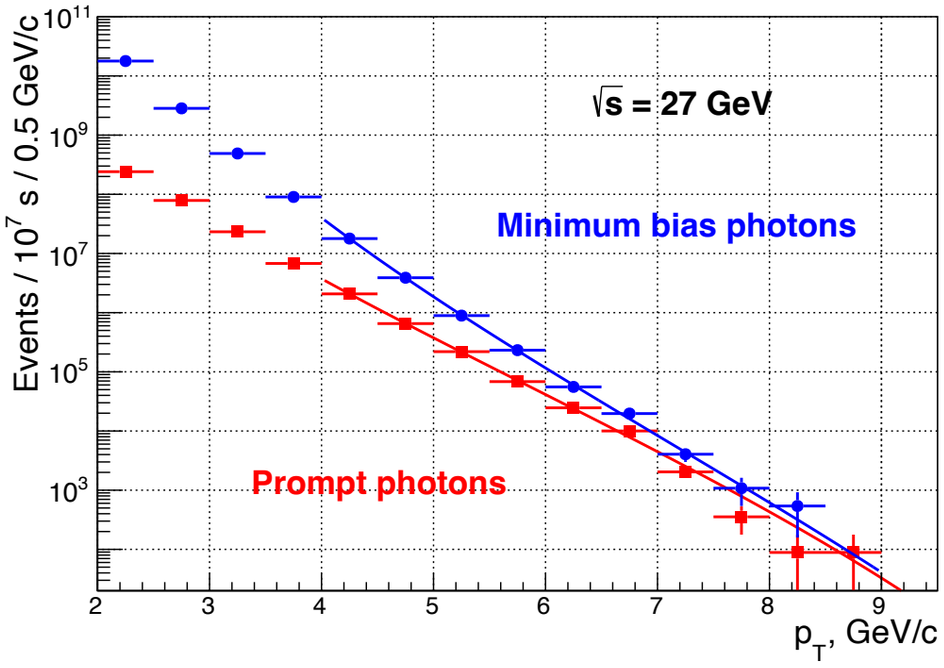
Physics performance: gluon probes

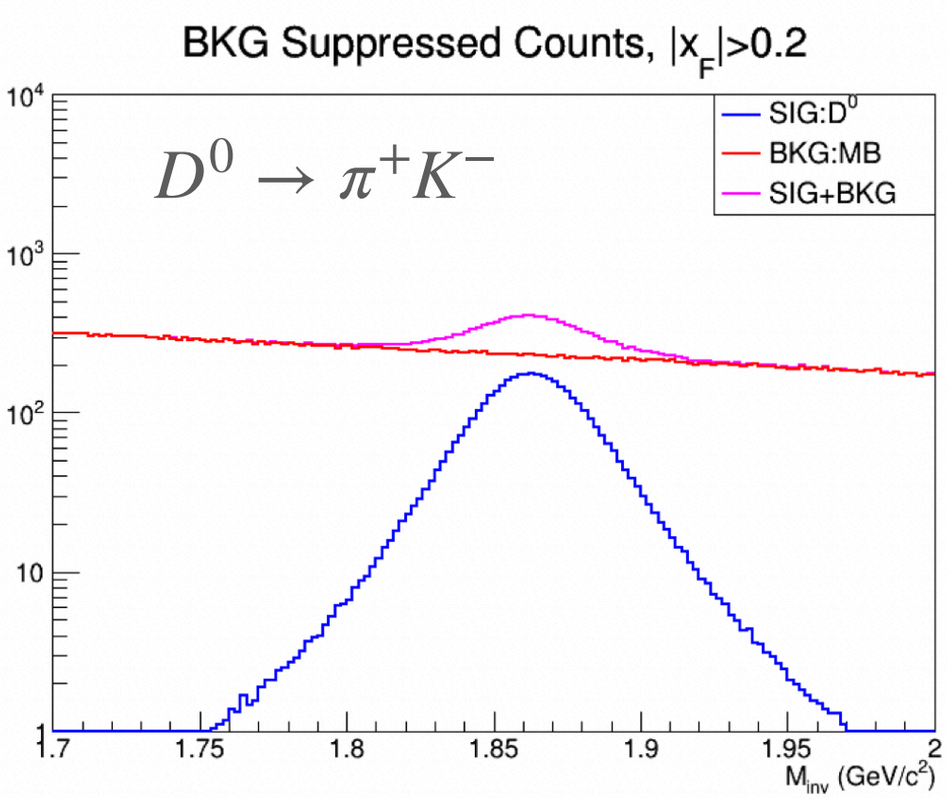
(1 year=10^7 s, 27 GeV)



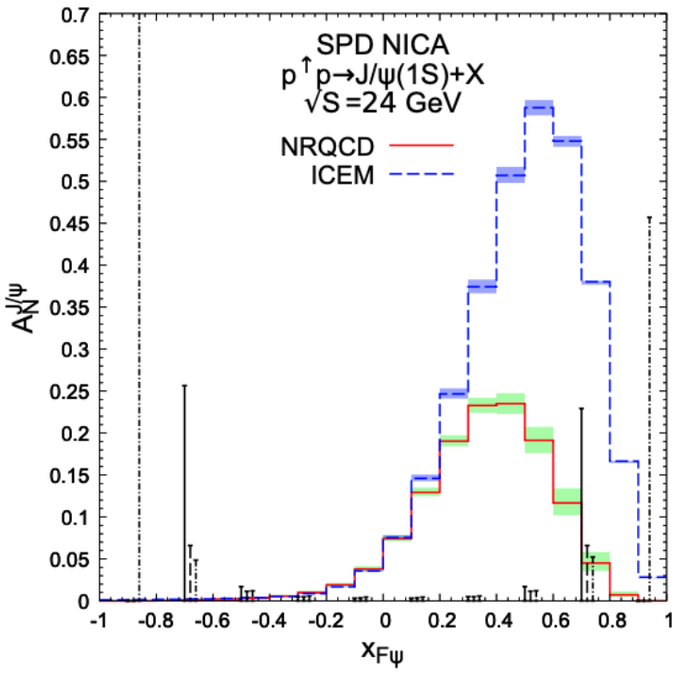




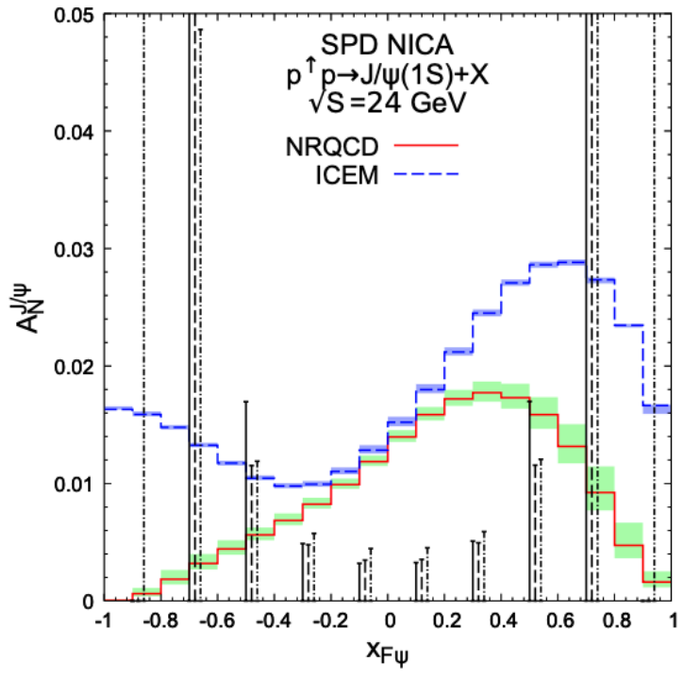


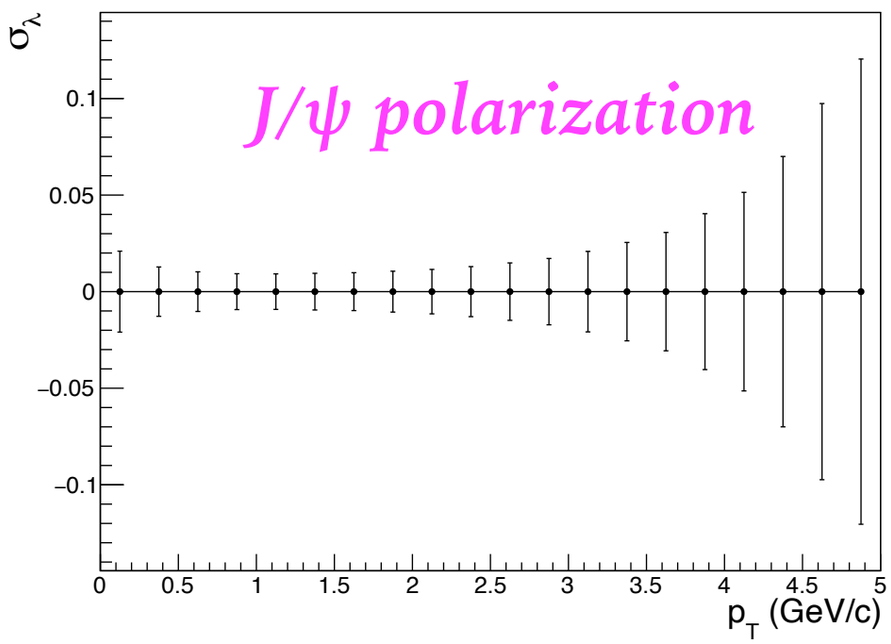


Physics performance: accuracies



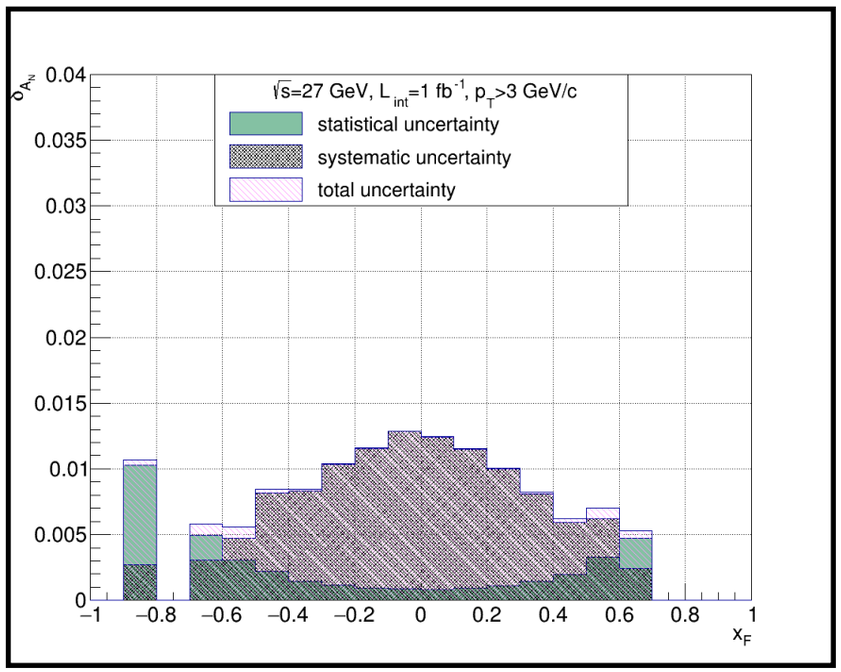
J/ψ



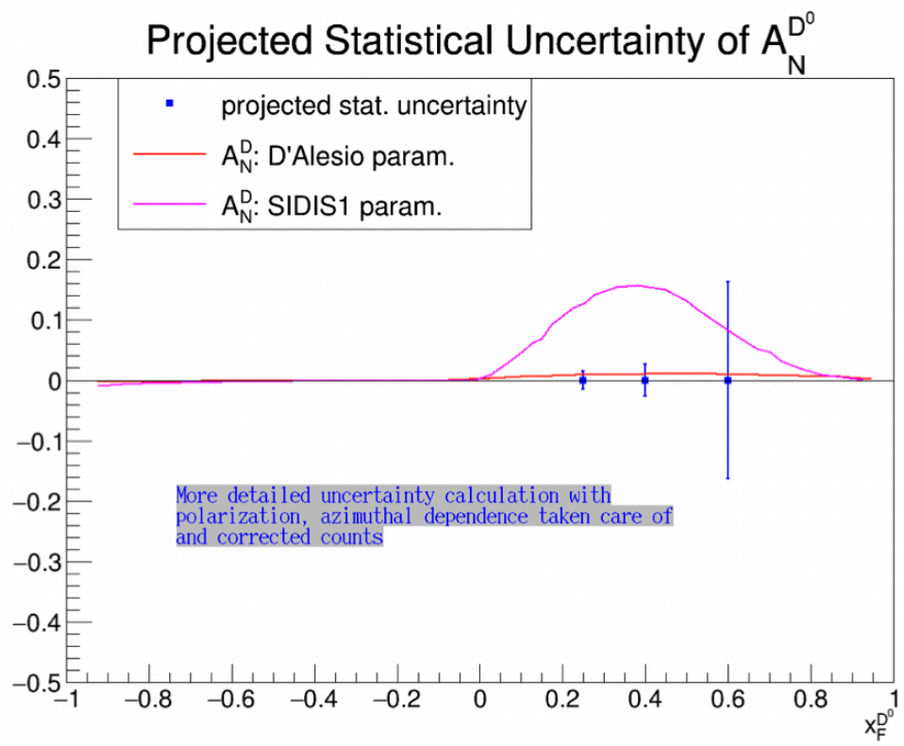


J/ψ polarization

Different inputs for gluon Sivers function

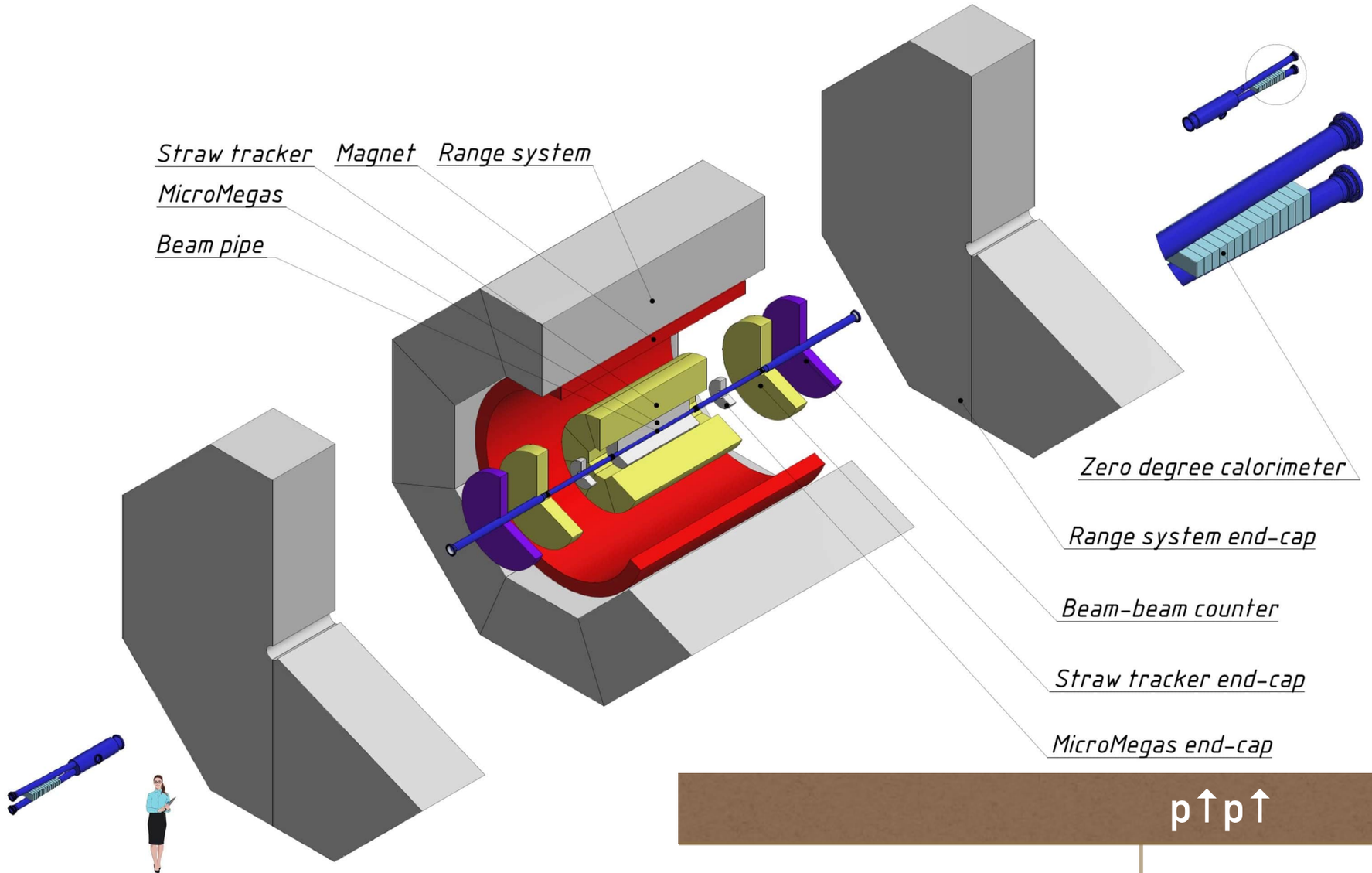


prompt-γ



D^0

SPD setup: 1st phase



	$p\uparrow p\uparrow$	$d\uparrow d\uparrow$	AA
	First phase		
$\sqrt{s_{NN}}$, GeV	< 9.4	< 4.5	< 4.5
L, 10^{30} cm^{-1} s^{-1}	< 10	< 1	< 0.001
	Second phase		
$\sqrt{s_{NN}}$, GeV	< 27	< 13.5	
L, 10^{30} cm^{-1} s^{-1}	< 100	< 10	

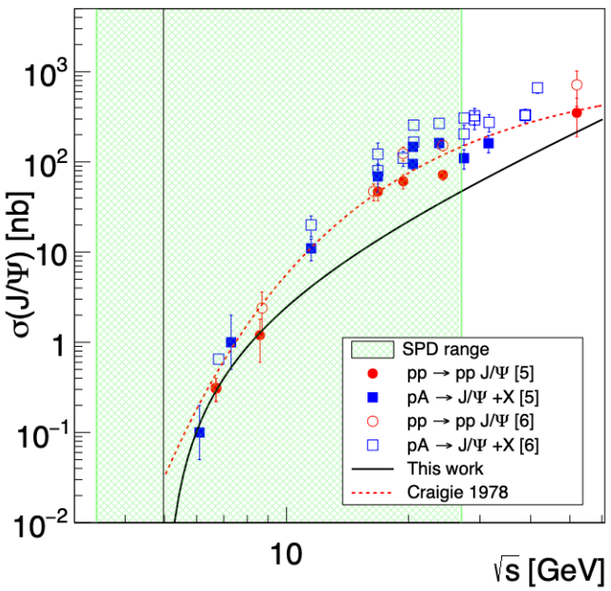
First-phase physics

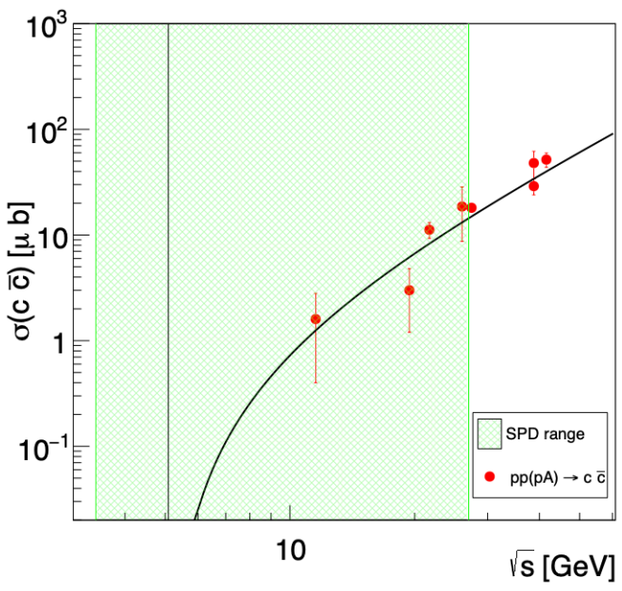
arXiv:2102.08477 *Phys.Part.Nucl.* 52 (2021) 6, 1044-1119

Non-perturbative QCD *Perturbative QCD*

$\sqrt{s}$

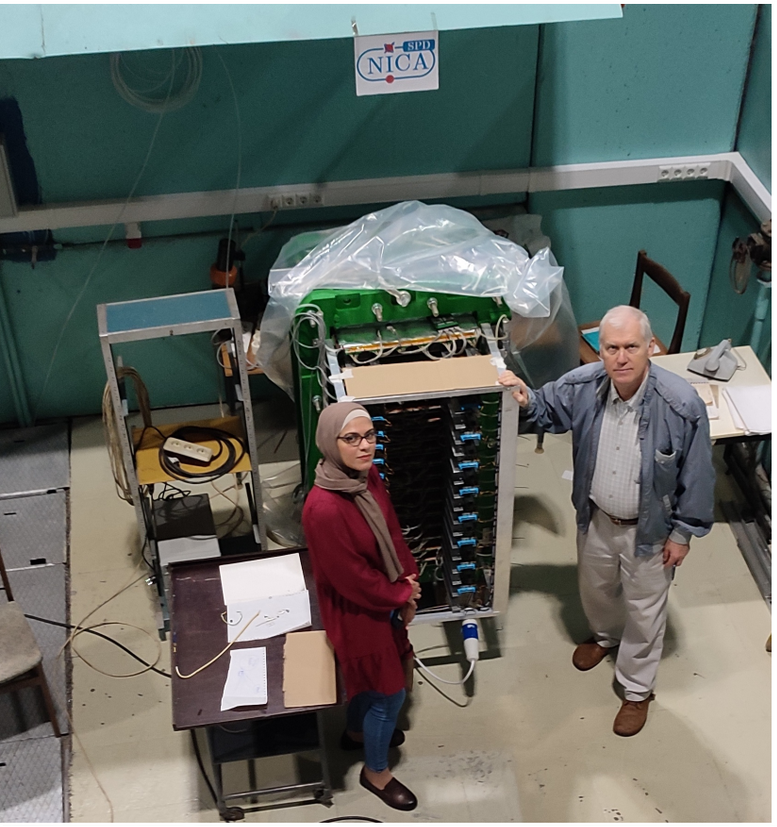
- Spin effects in p-p, d-d elastic scattering
- Spin effects in hyperons production
- Multiquark correlations $pp \to (6q)^* \to N\,N\,Mesons,$
- Dibaryon resonances
- Physics of light and intermediate nuclei collision
- Exclusive reactions
- Hypernucei $dd \to K^+\,K^+\,{}^{4}_{\Lambda\Lambda}\mathrm{n},$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



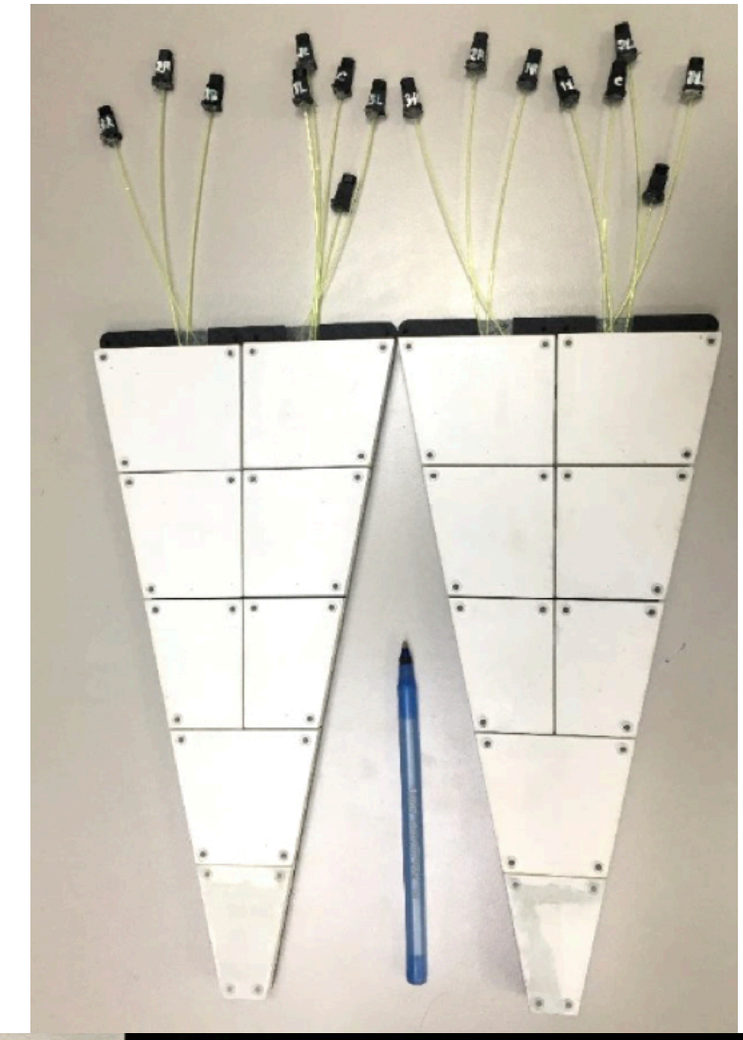


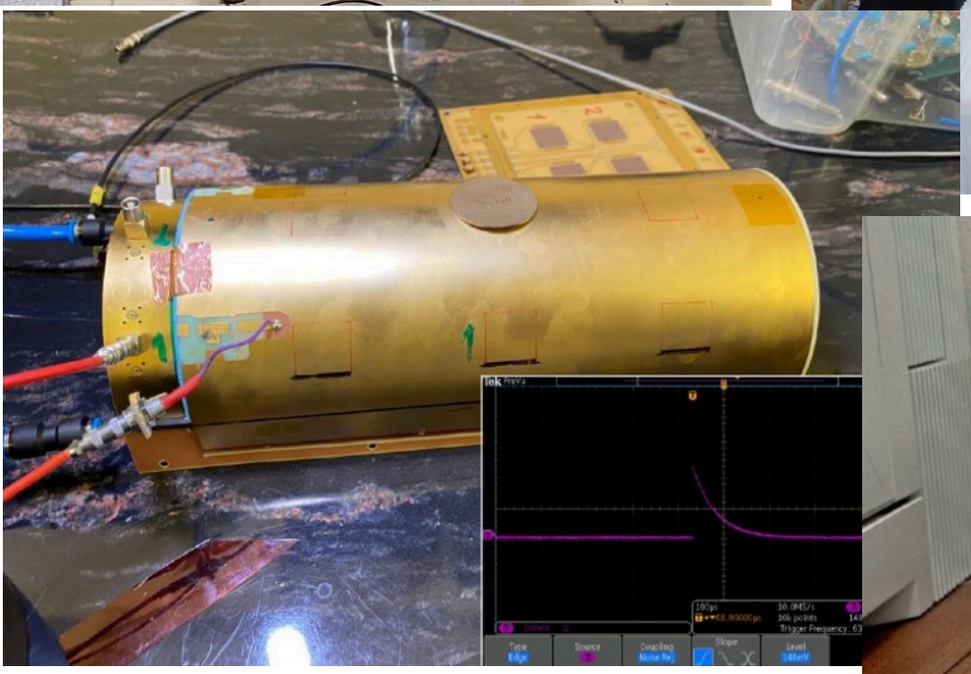
- Auxiliary measurements for astrophysics
- ...

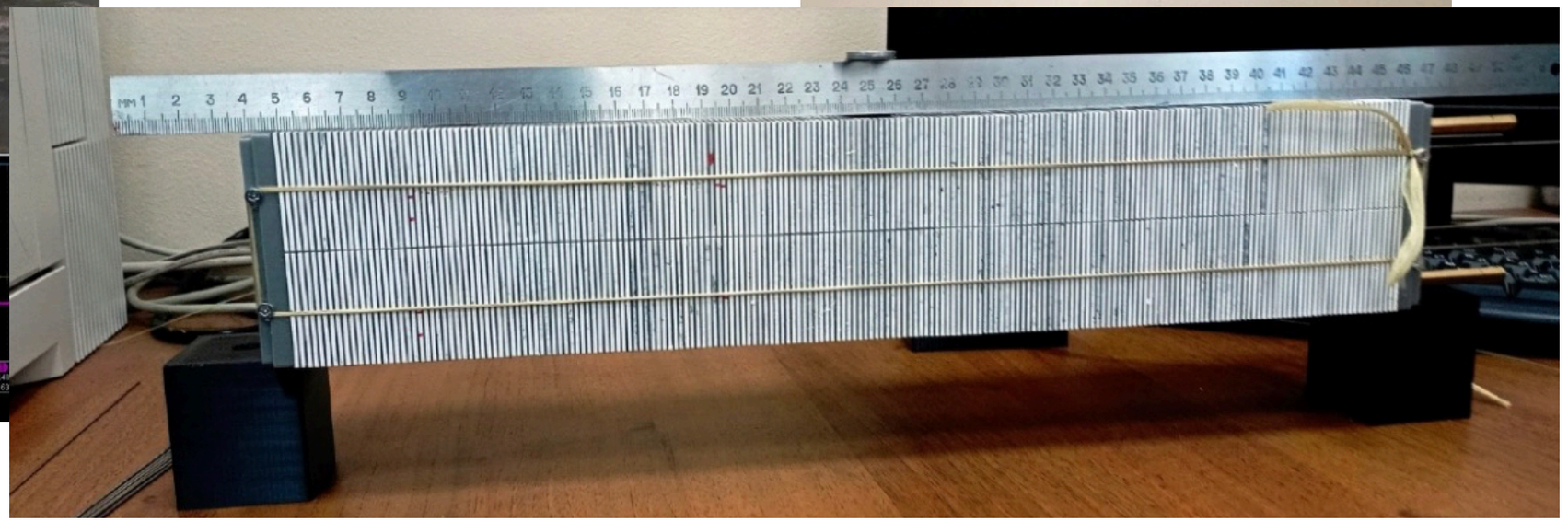
Detector prototyping





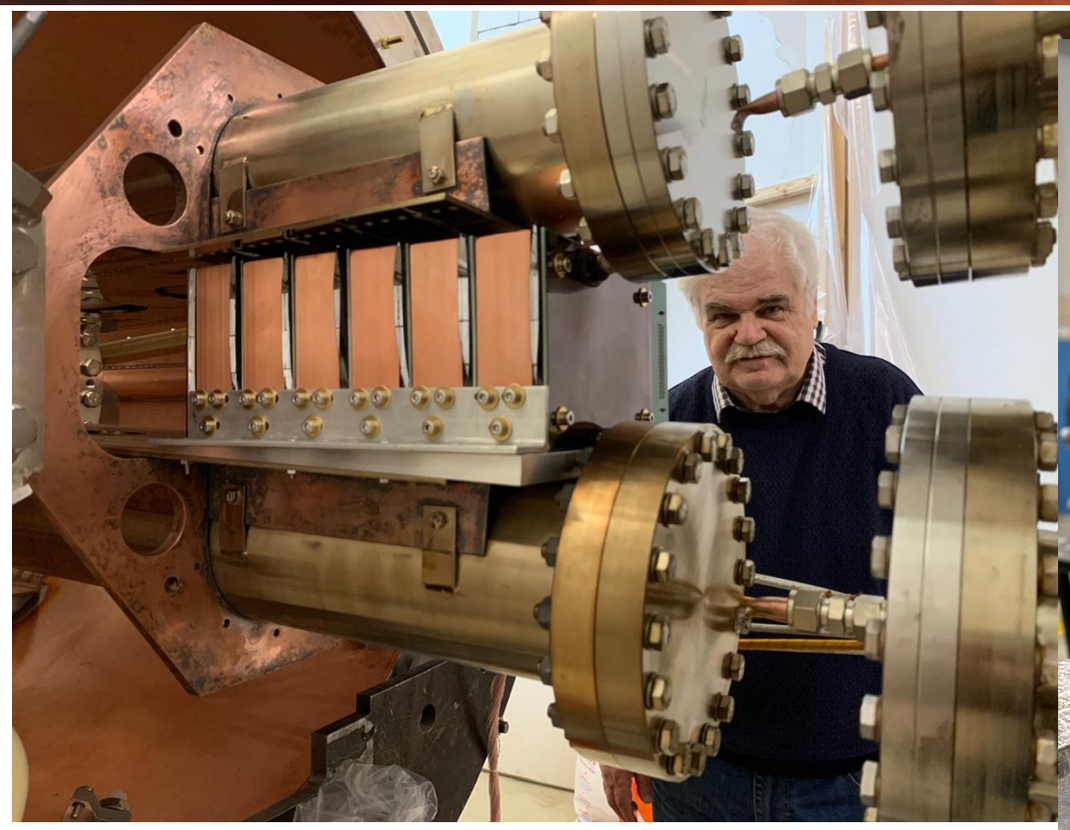






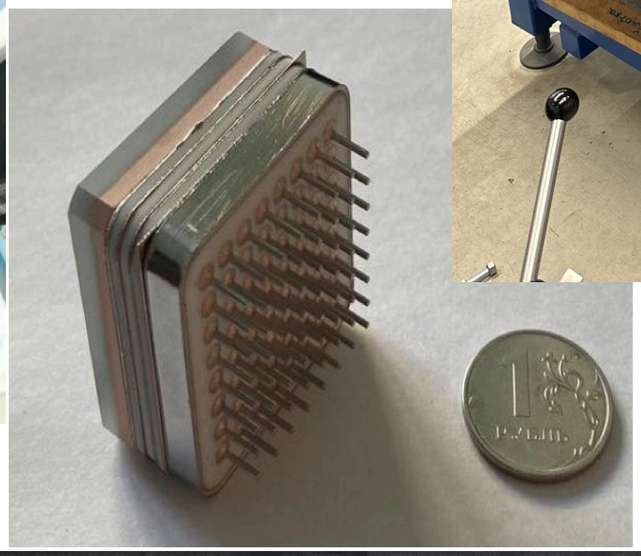
Detector prototyping











SPD experimental hall









Status of the SPD project

SPD **Technical Design Report** passed international expertise and published:
Natural Sci. Rev. 1 1 (2024)
https://arxiv.org/abs/2404.08317

The **first phase** of the SPD project is included into the JINR's 7-year plan (2024-2030)

The **SPD collaboration** currently consists of more than 30 institutes from 15 countries and more than 400 participants

We started to construct our experimental setup!





Decade 2030+


u
u
d
QCD & spin hadron physics
DIS: Electro-ion colliders
EIC, EicC and JLAB
Hadron colliders:
SPD NICA
Fixed-target experiments:
LHCspin, DY, etc

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**, 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 exps, AFTER, LHC-Spin, EIC, JLab exps, EicC, …)**
- More information about the SPD project can be found at http://spd.jinr.ru .

BACKUP SLIDES

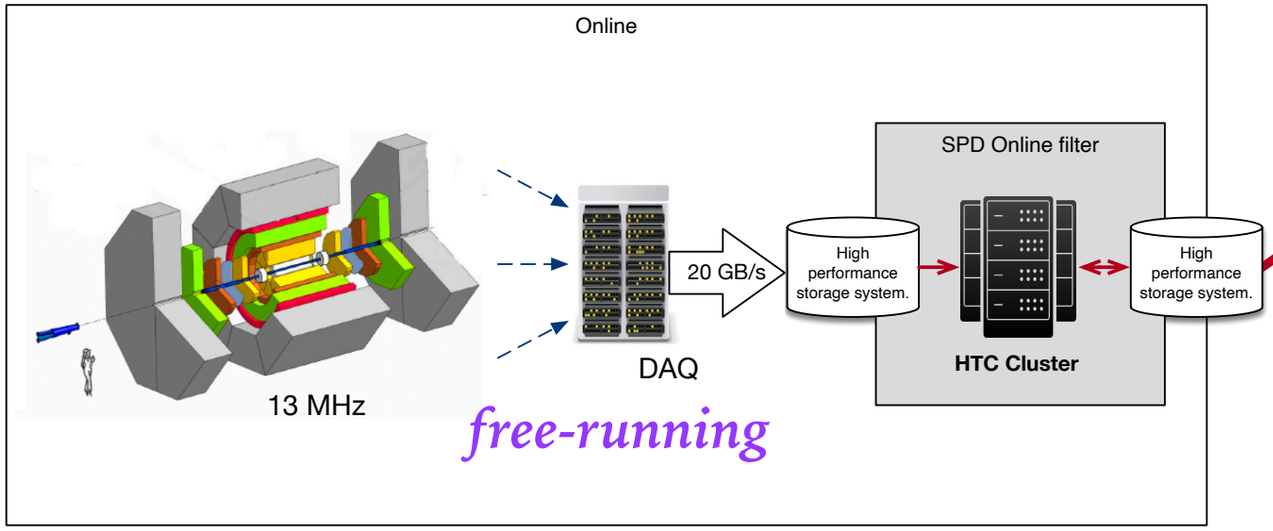
SPD setup: basic properties

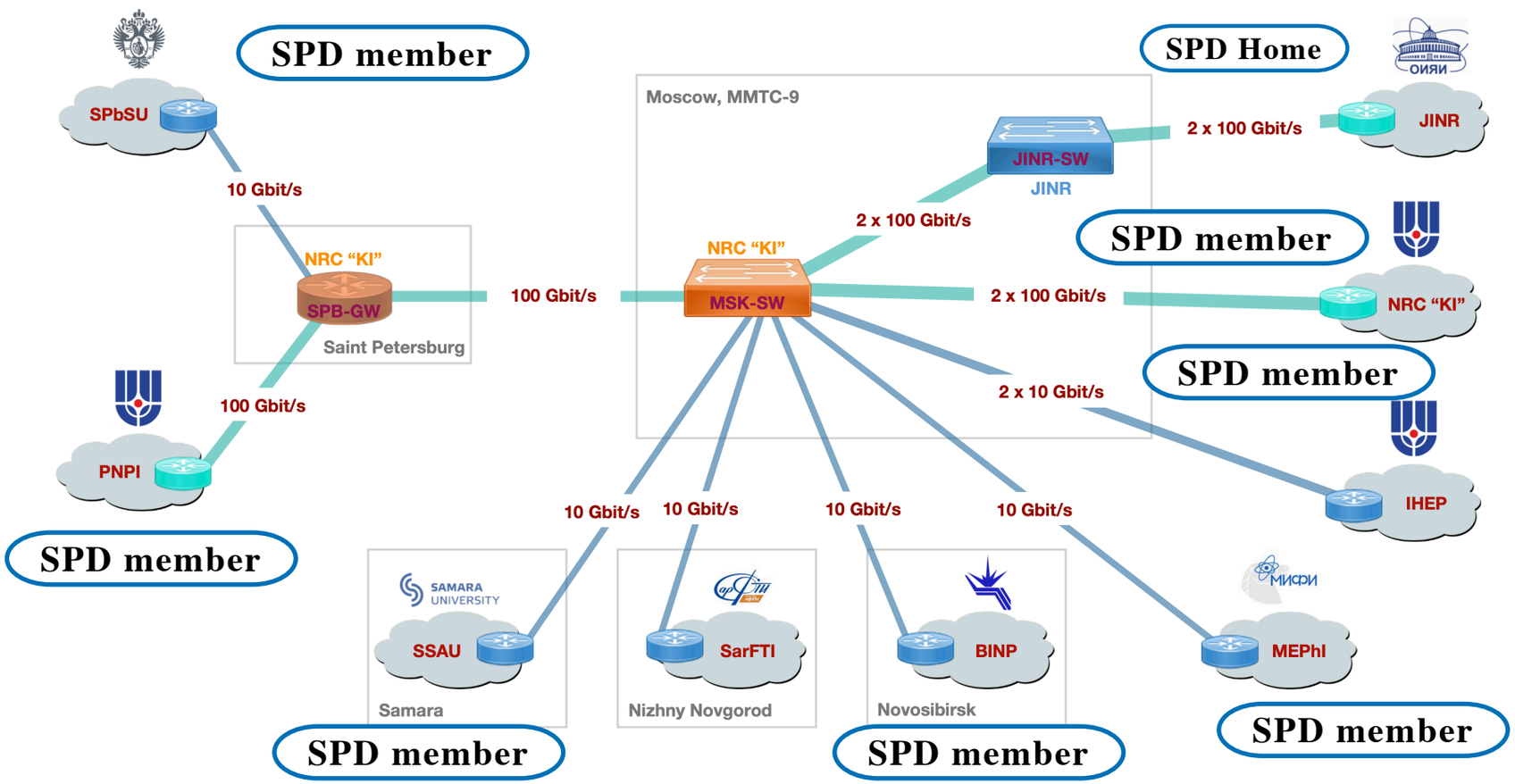
	Stage I	Stage II
Maximum luminosity, 10^{32} cm^{-2} s^{-2}	up to 0.1	1
Interaction rate, MHz	up to 0.4	4
Magnetic field at IP, T	up to 1.0	1.0
Track momentum resolution $\frac{\delta p}{p}$ at 1 GeV/c, %	~1.7	~1.0
Photon energy resolution, %		$5/\sqrt{E} \oplus 1$
$D^0 \to K\pi$ vertex spatial resolution, μm		60 for MAPS
		80 for DSSD
PID capabilities	dE/dx, RS	dE/dx, ECal, RS, TOF, FARICH
Number of channels, 10^3	170	294 for MAPS)
	210	397 for DSSD
Raw data flow, GB/s	up to 1	up to 20
Total weight, t	1236*	1240
Power consumption, kW	77	113 for MAPS
		90 for DSSD

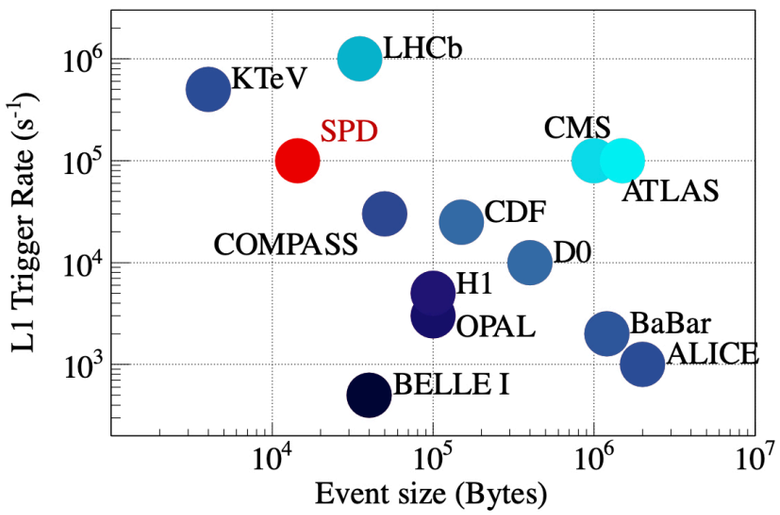
Detector	Spatial resolution	Time resolution	Energy resolution	Signal length
RS	3 mm (wires), 1 cm (strips)	150 ns	$90\%/\sqrt{E}$ (p, n)	250÷500 ns
ECal	5 mm (γ, 1 GeV)	1 ns	$5\%/\sqrt{E} \oplus 1\%$	
TOF	10 cm	50 ps	–	
FARICH		<1 ns	$d\beta/\beta < 10^{-3}$	10 ns
Straw	150 μm	1 ns	$8.5\%(dE/dx)$	120 ns
SVD MAPS	5 μm	–	–	
SVD DSSD	27.4 μm (ϕ)	–	–	
	81.3 μm (z)			
MCT	150 μm	10 ns	–	~ 300 ns
BBC inner	1.5 mm	50 ps	–	
BBC outer	~ 10 cm	400 ps	–	
ZDC	~ 1 cm	150 ps at 0.4 GeV	$50\%/\sqrt{E} \oplus 30\%$ (n)	
			$20\%/\sqrt{E} \oplus 9\%$ (γ)	

IT infrastructure

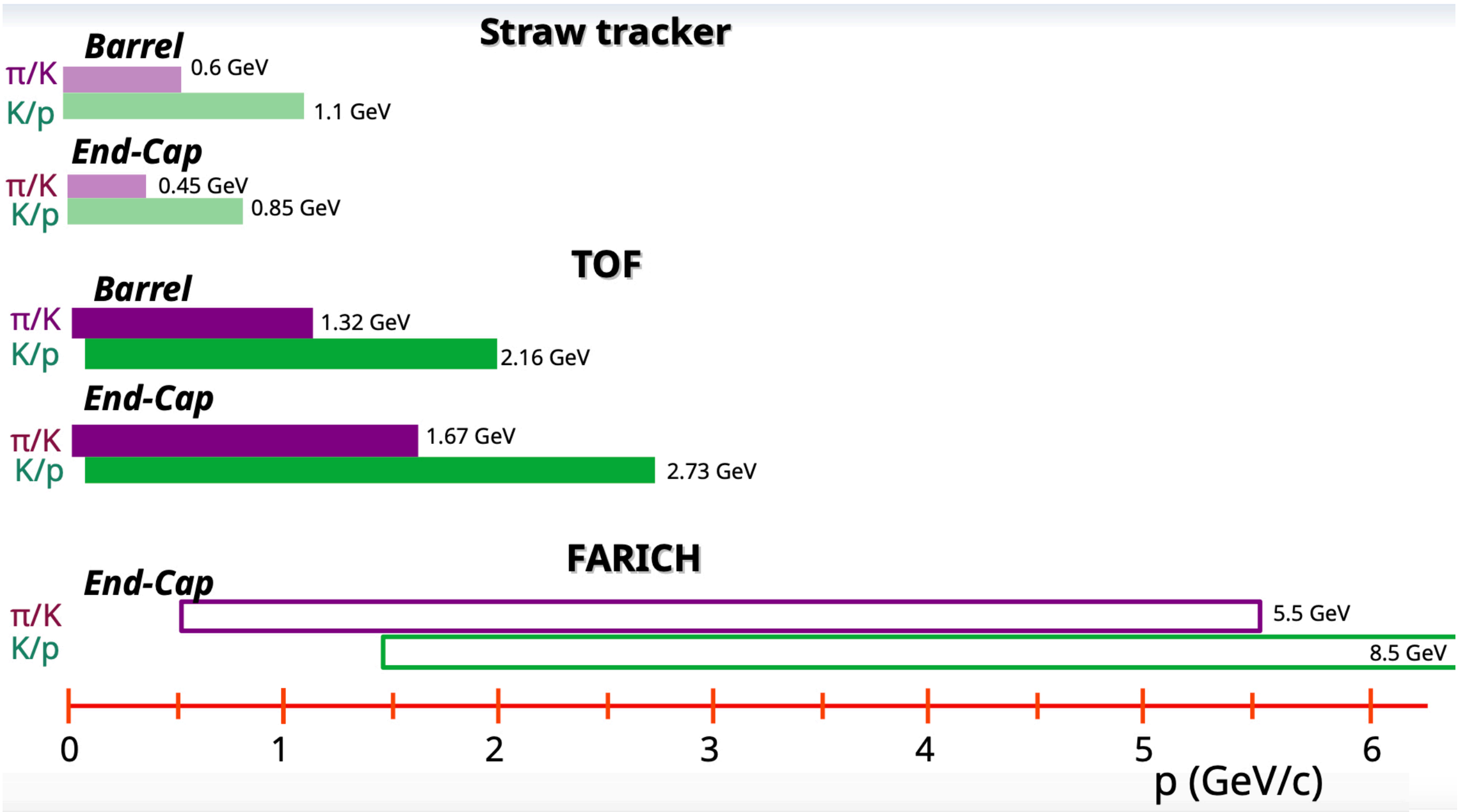
SPD data flow





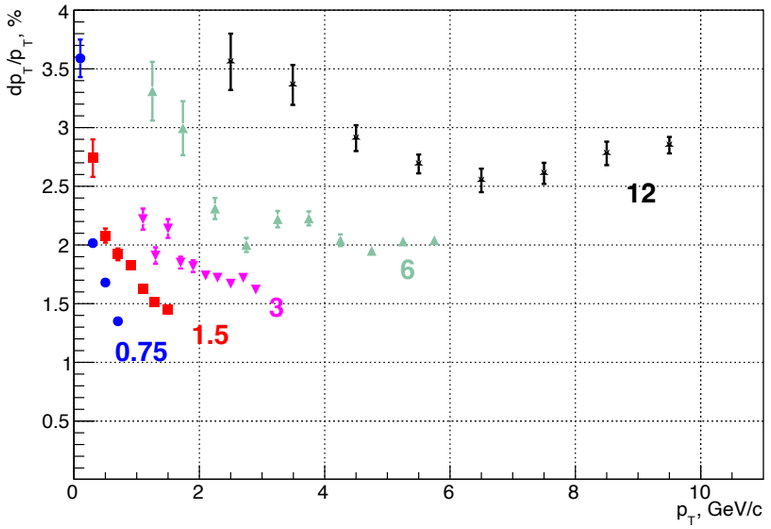


PID capabilities

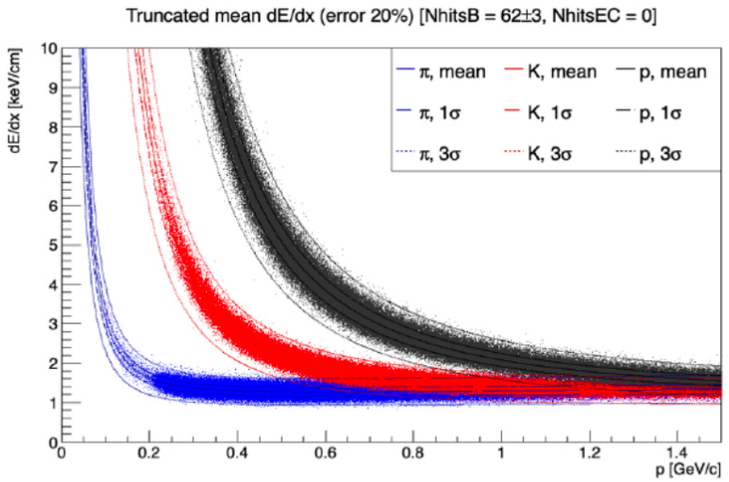


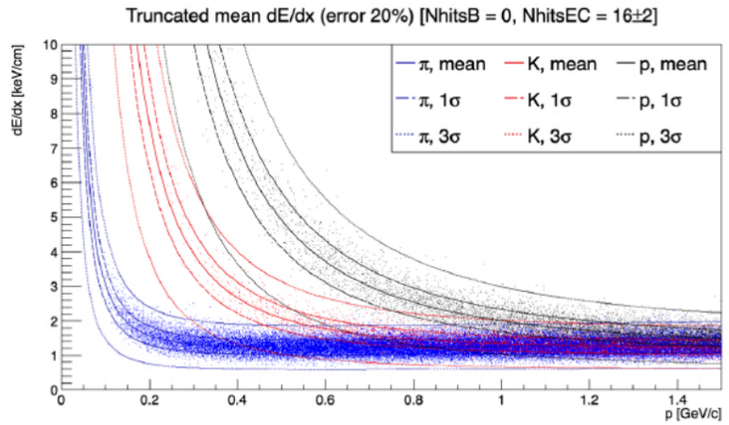
Detector performance

Momentum resolution



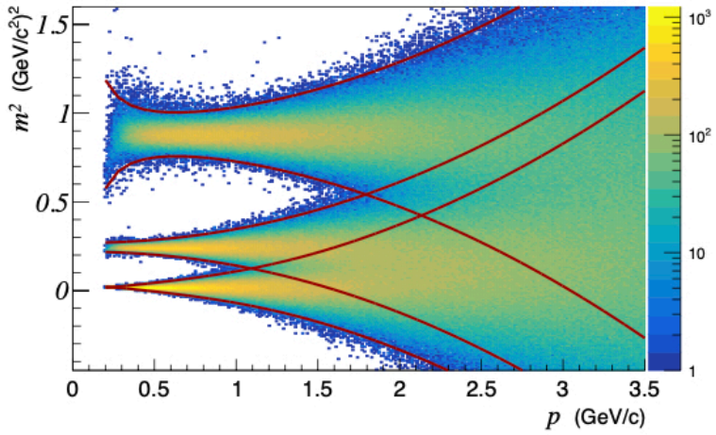
dE/dx in Straw tracker



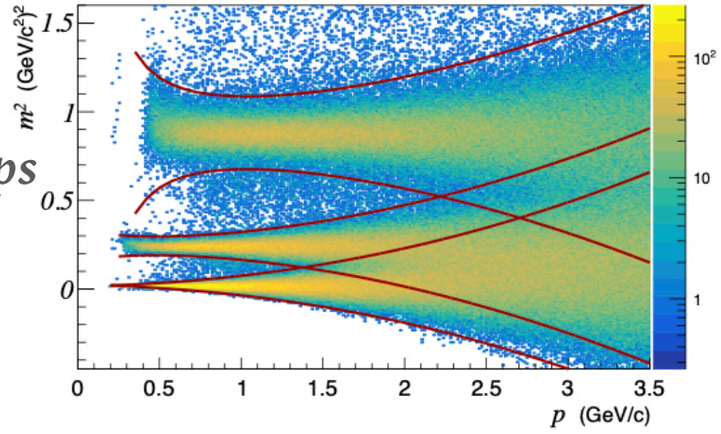


TOF performance

barrel



endcaps



FARICH performance

