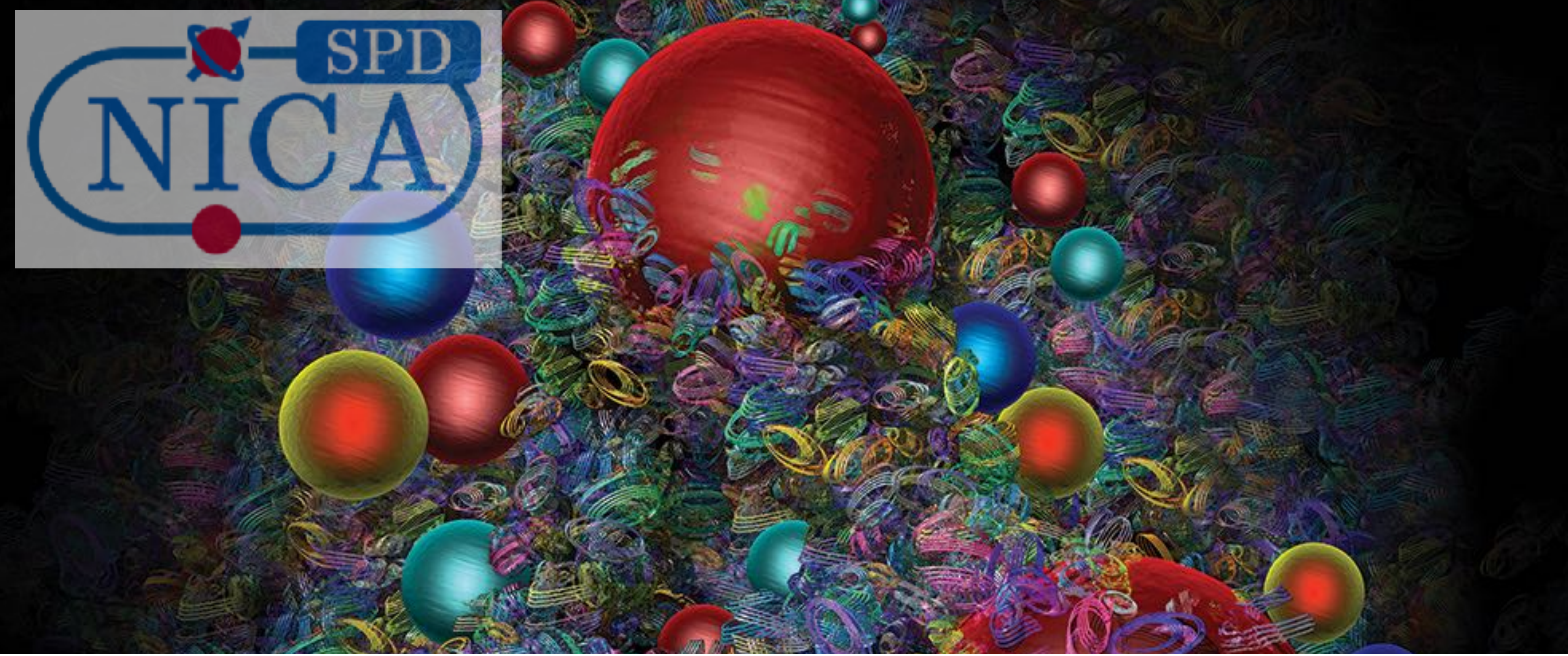


Review of the SPD program and detector

A. Guskov (DLNP, JINR)
on behalf of the SPD working group:

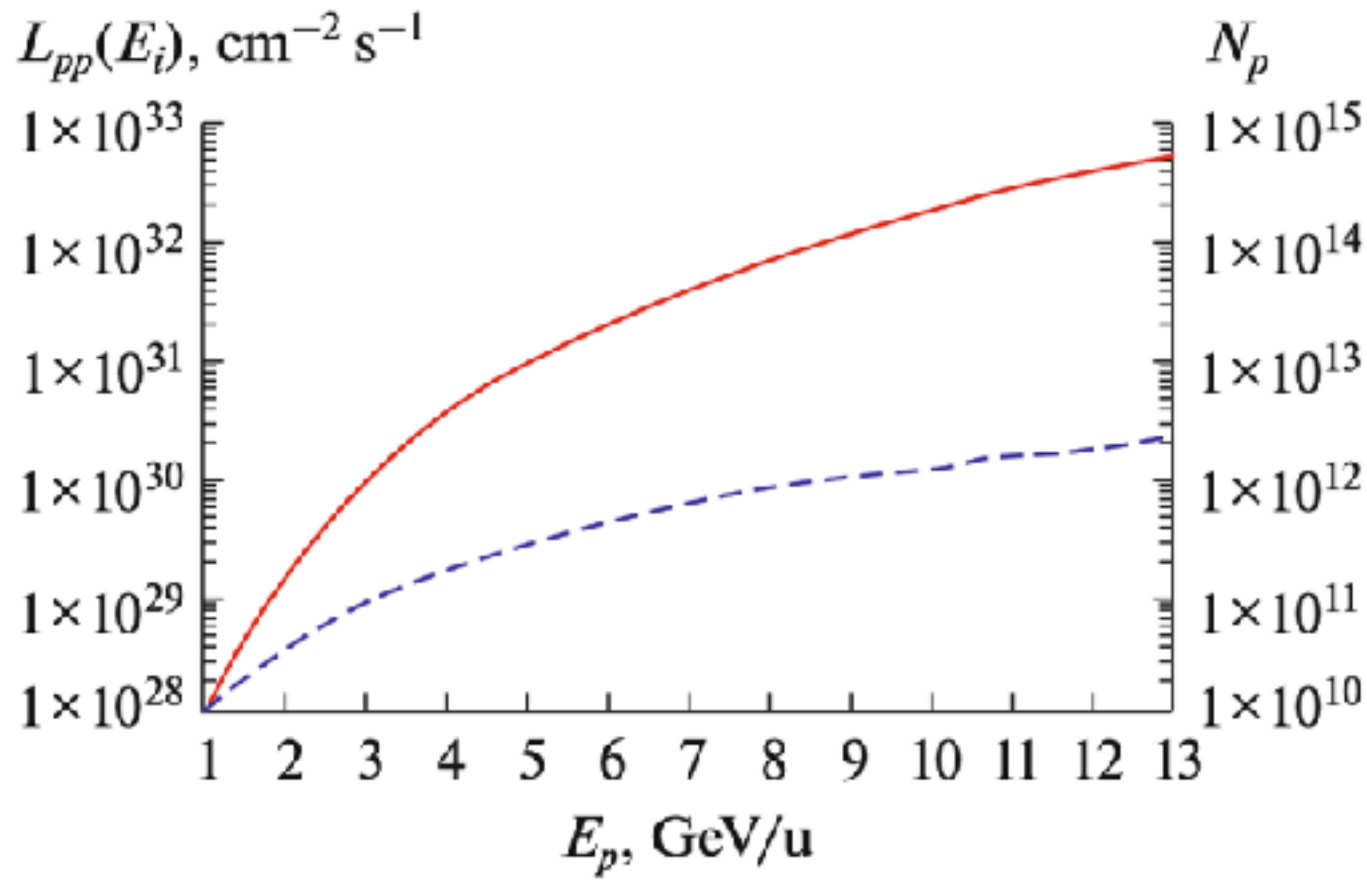
21.10.2020

THE NUCLOTRON-BASED ION COLLIDER FACILITY (NICA) PROJECT AT JINR

SPD – EXPERIMENTAL CONDITIONS

circumference	- 503 m,
number of collision points (IP)	- 2,
beta function β_{min} in the IP	- 0.35 m,
number of protons per bunch	- $\sim 1 \cdot 10^{12}$,
number of bunches	- 22,
RMS bunch length	- 0.5 m,
incoherent tune shift, $\Delta_{Lasslett}$	- 0.027,
beam-beam parameter, ξ	- 0.067,
beam emittance ε_{nrm} (normalized) at 12.5 GeV, π mm mrad	- 0.15.

$|P| > 0.6$



Beam energies:

$p\uparrow p\uparrow(\sqrt{s_{pp}}) = 12 \div \geq 27$ GeV ($5 \div \geq 12.6$ GeV of proton kinetic energy),

$d\uparrow d\uparrow(\sqrt{s_{NN}}) = 4 \div \geq 13.8$ GeV ($2 \div \geq 5.9$ GeV/u of ion kinetic energy).

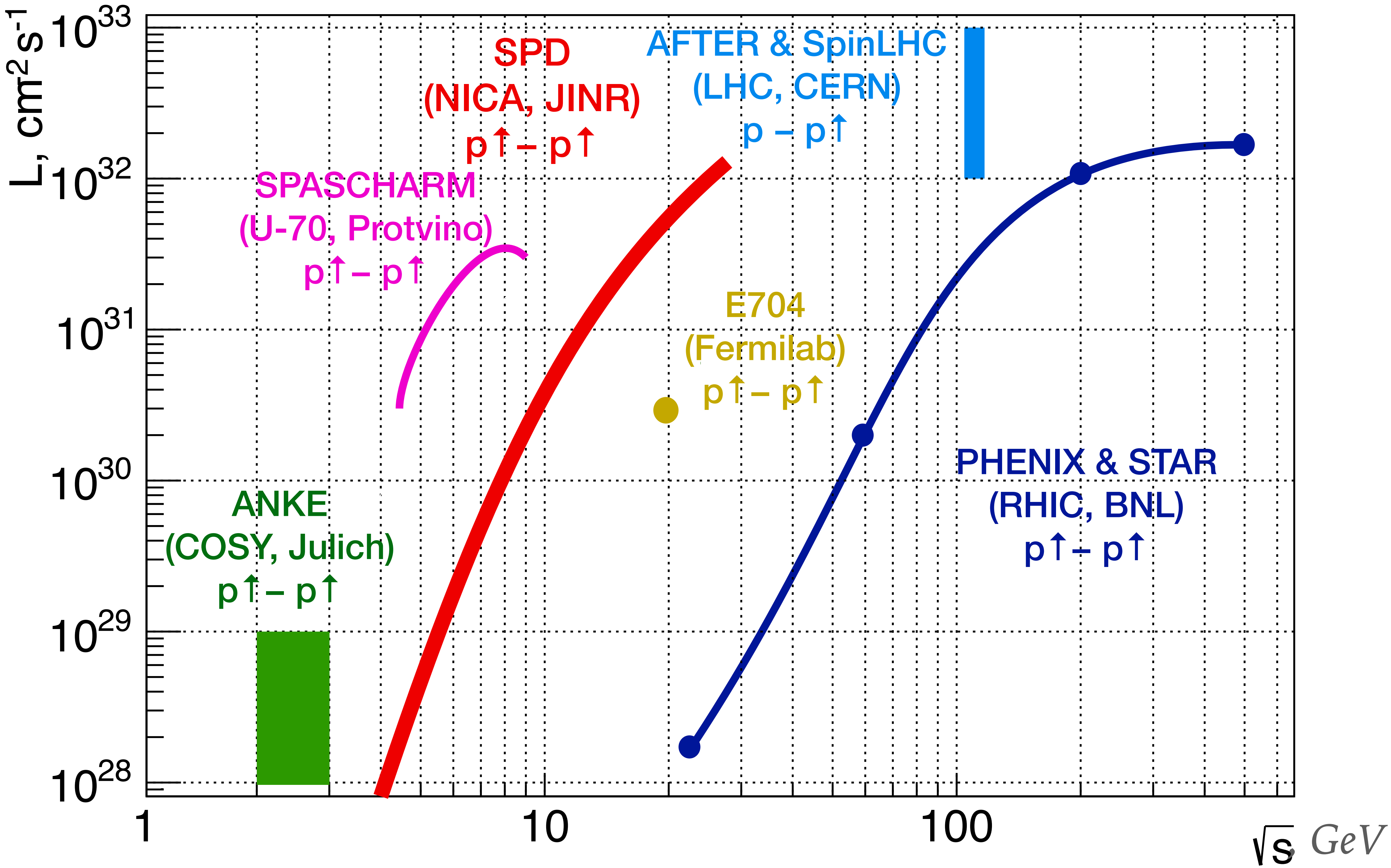
Unique possibility!

also $p\uparrow d\uparrow$

All combinations of collisions are possible -

UU, LL, TT, UL, UT, LT

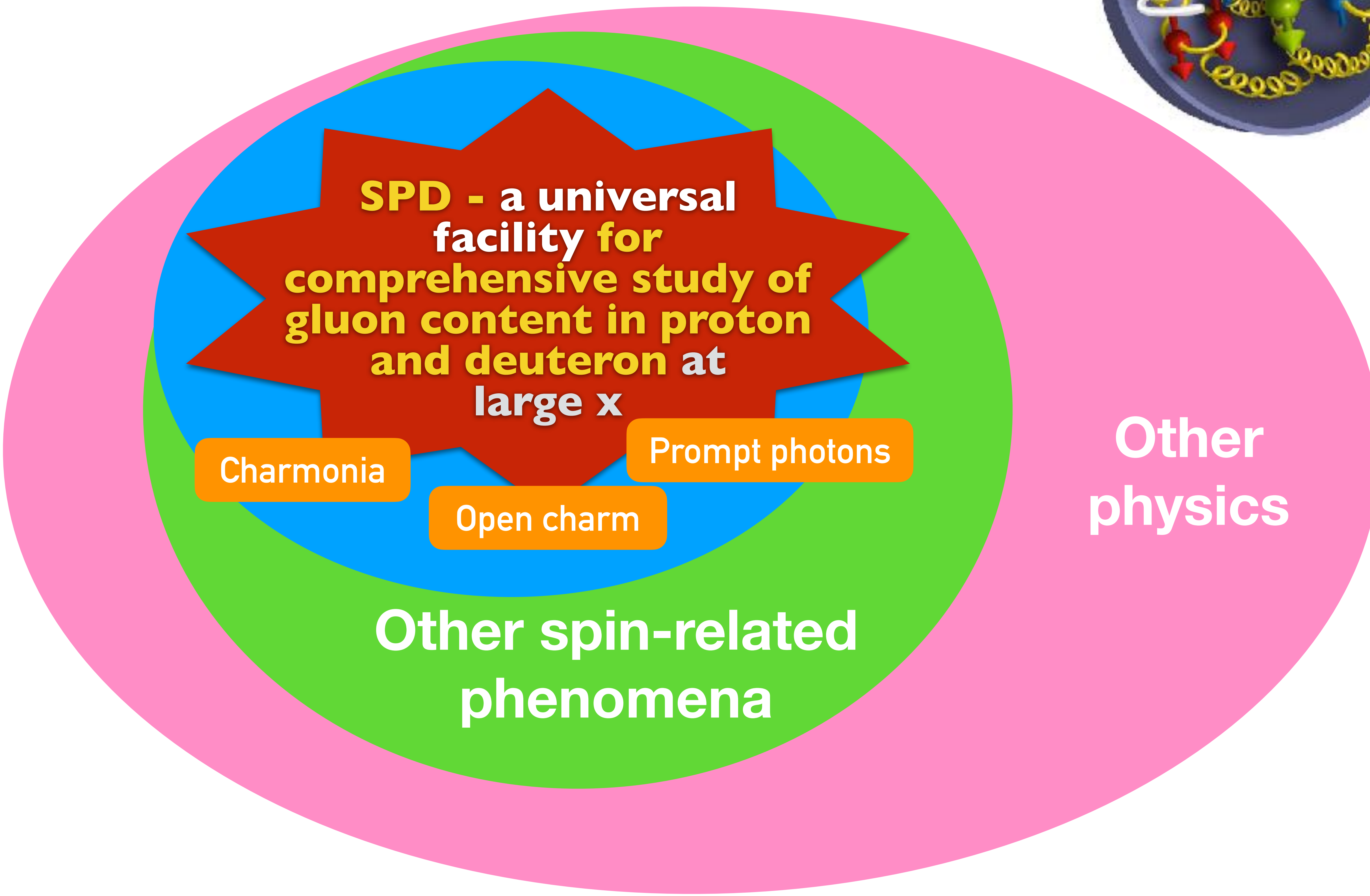
SPD – VS OTHER POLARIZED p-p EXPERIMENTS



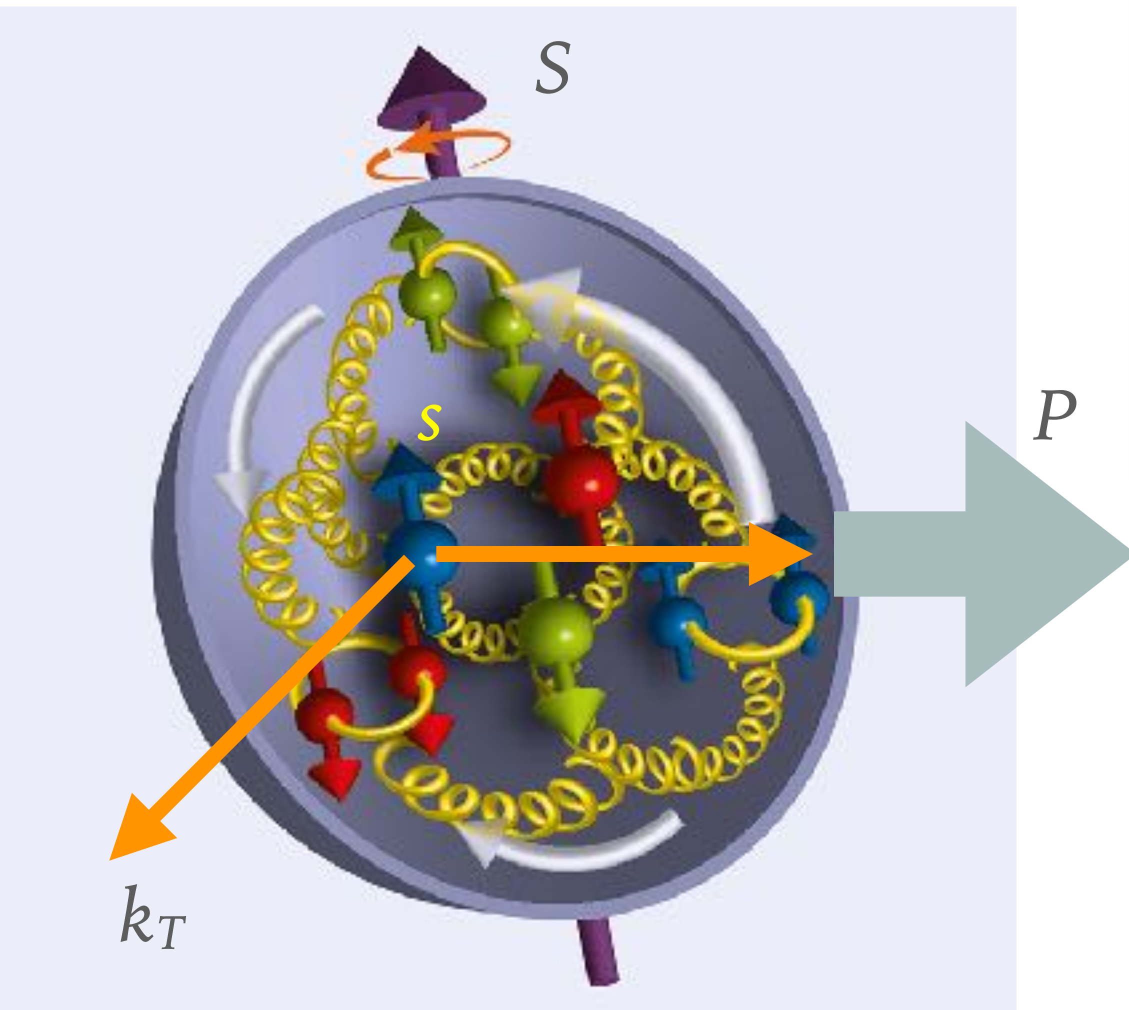
MAIN PLAYERS IN POLARIZED GLUON PHYSICS

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

CONCEPT OF THE SPD PHYSICS PROGRAM



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

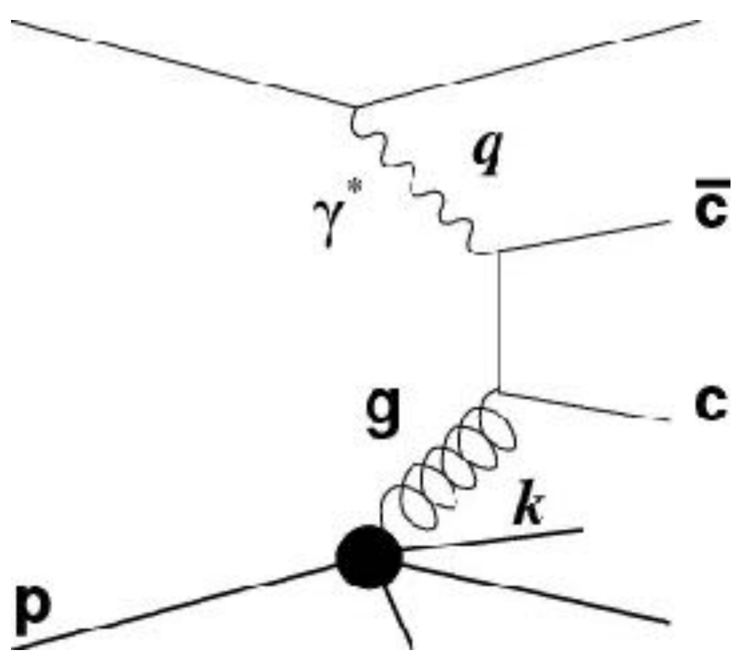
Spin of proton

Spin of parton

Transverse momentum of parton

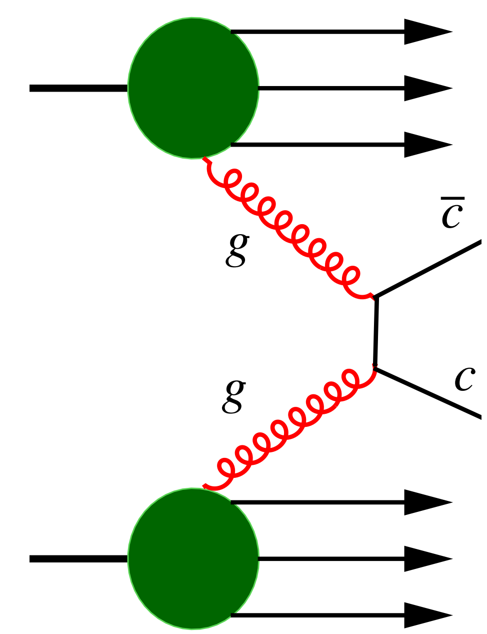
WHY GLUONS?

We cannot compete with SIDIS experiments in the study of the quark content of the nucleon



SIDIS

$$\sigma \sim \alpha^2 \alpha_s$$

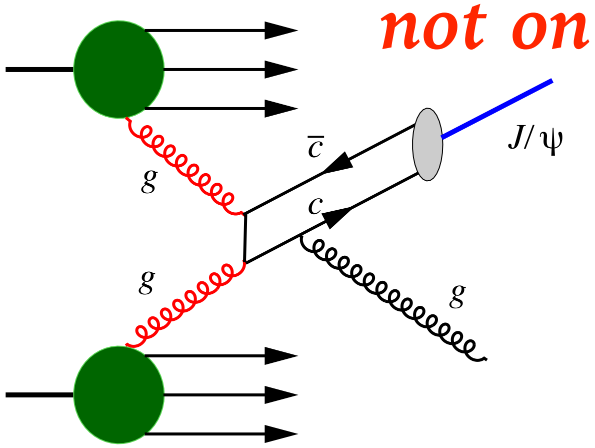


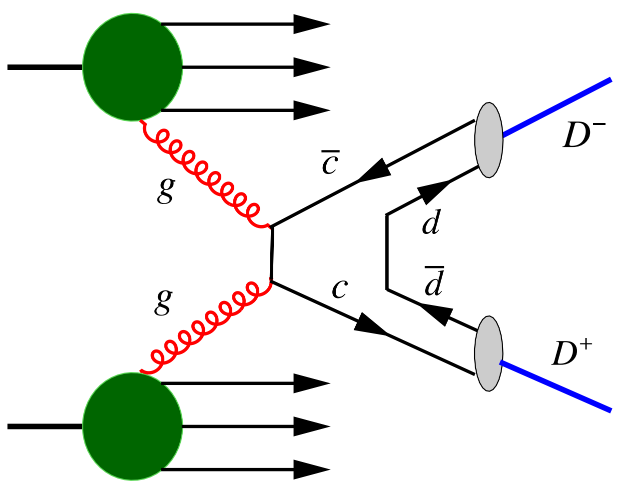
Hadroproduction

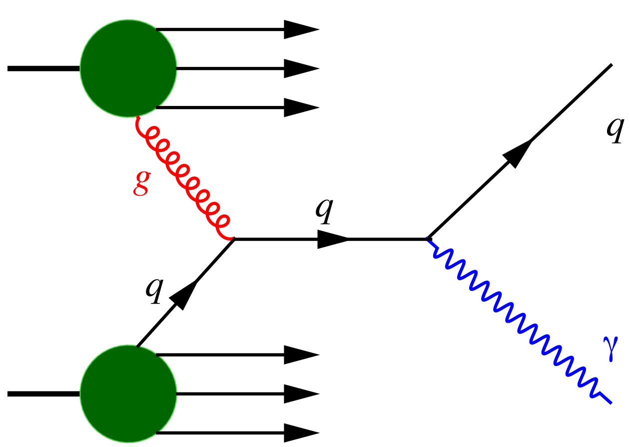
$$\sigma \sim \alpha_s^2$$

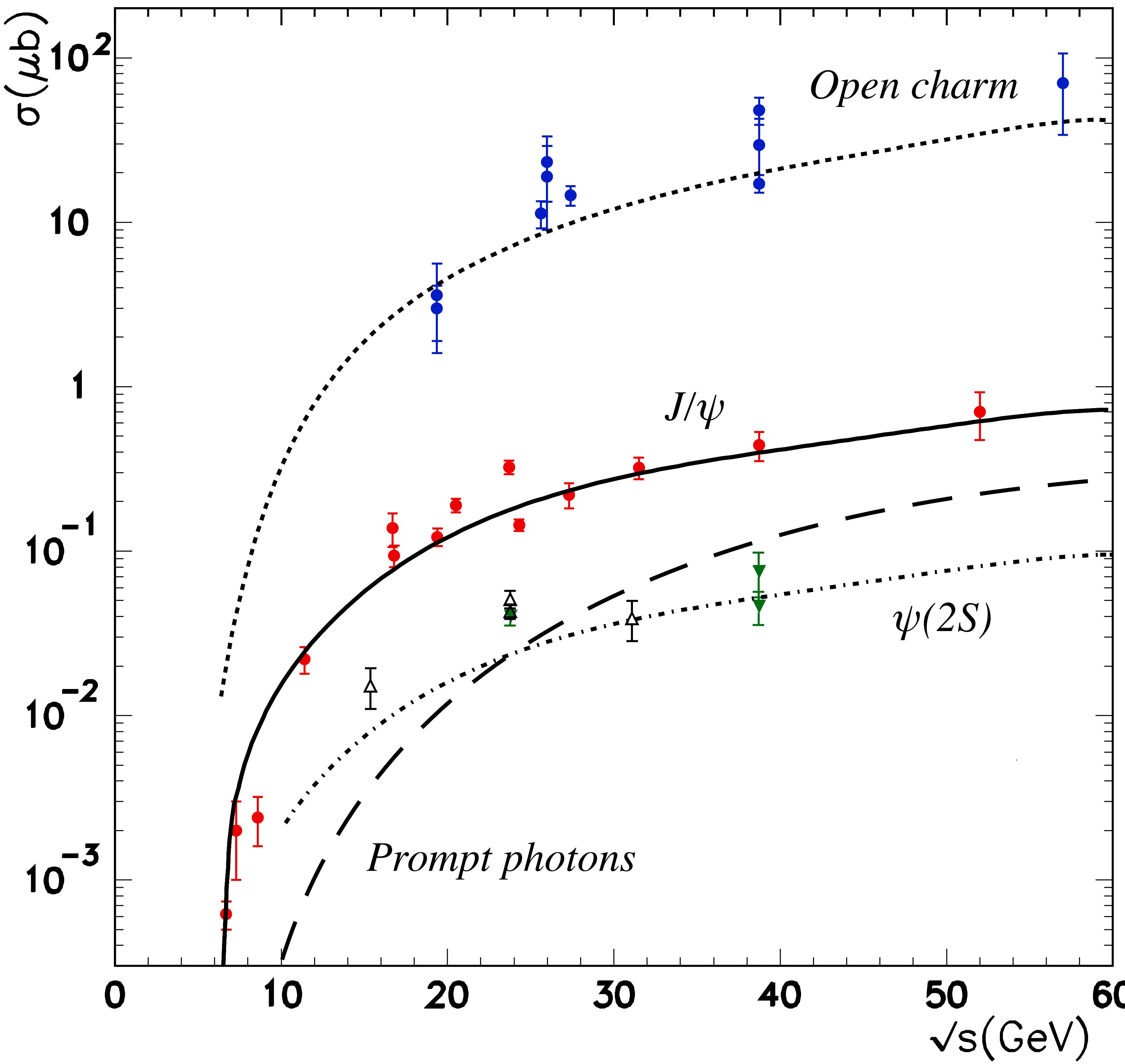
GLUON PROBES AT SPD

not only J/ψ!

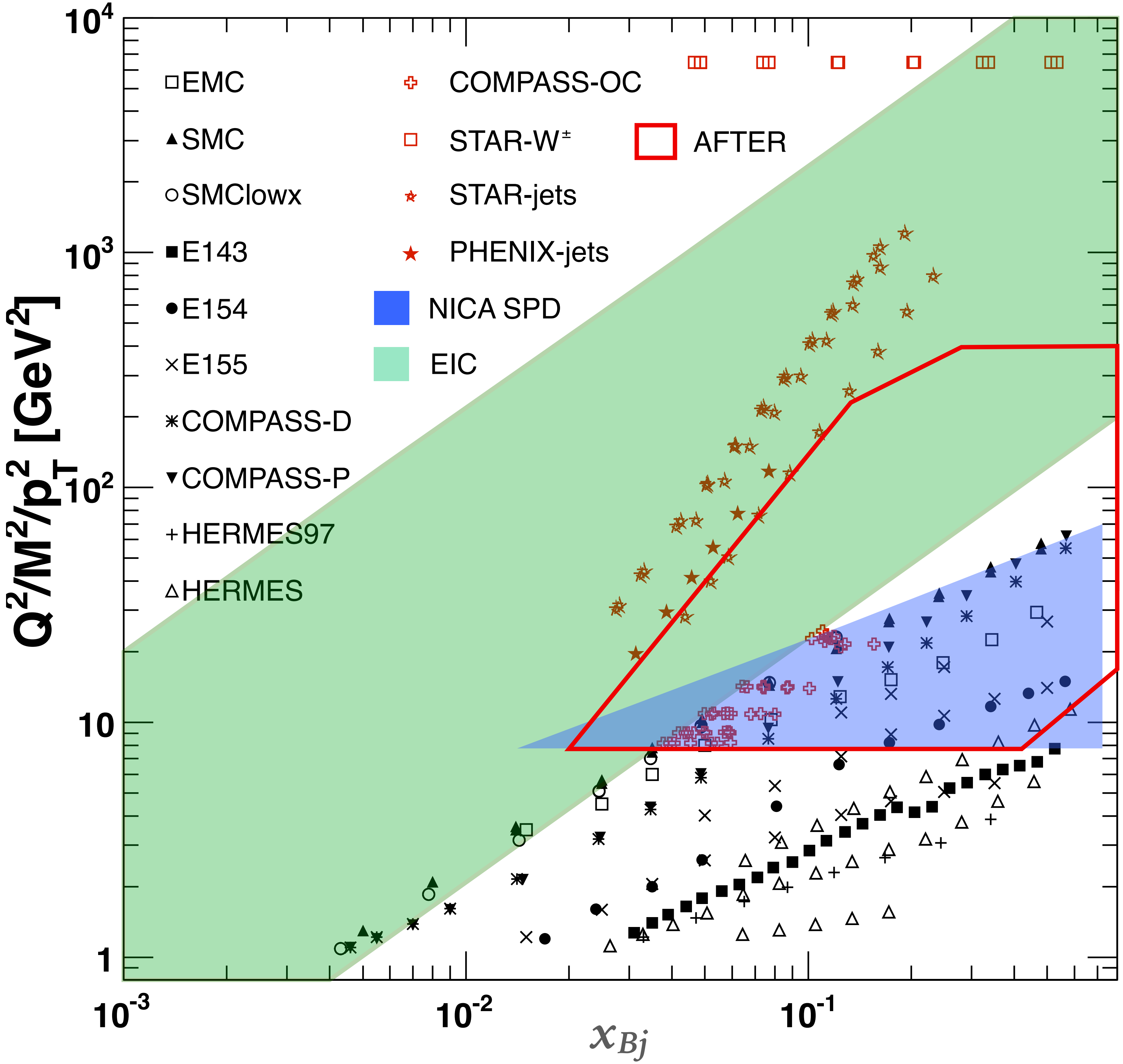








MAIN PLAYERS IN POLARIZED GLUON PHYSICS



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

open charm

charmonia

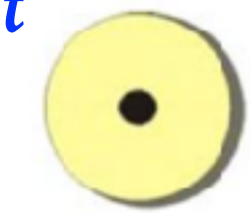
high-p_T prompt photons

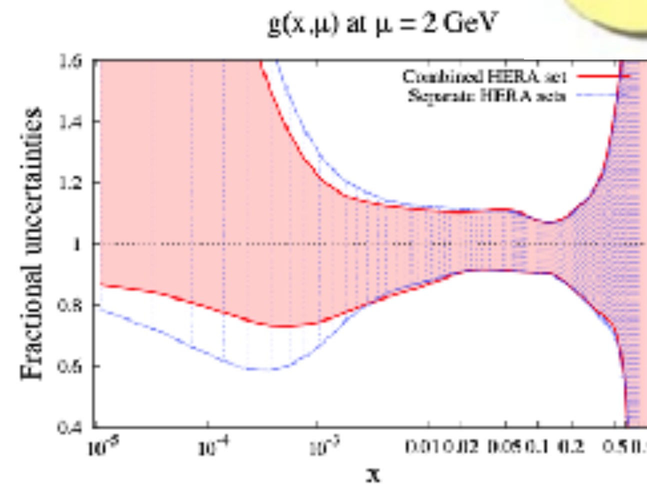
PARTONIC STRUCTURE OF PROTON AND DEUTERON

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

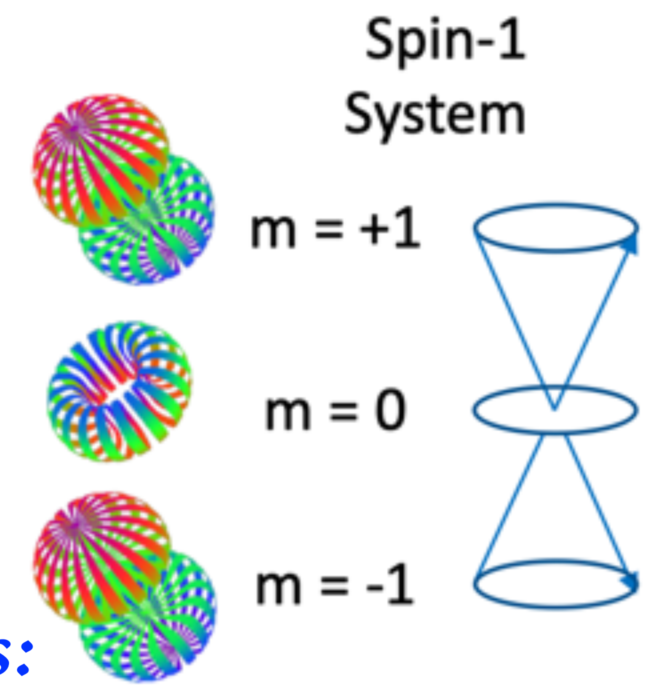
$A_{TT}(x_F,p_T)$ $A_N(x_F,p_T)$

Unpolarized gluons in proton and deuteron at high x:



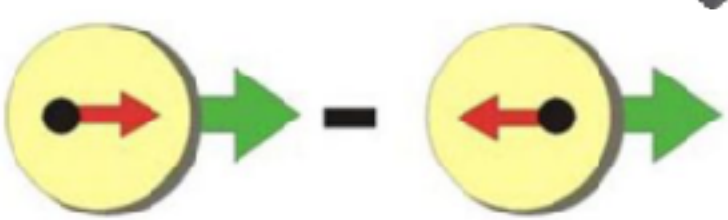


Tensor structure of deuteron:

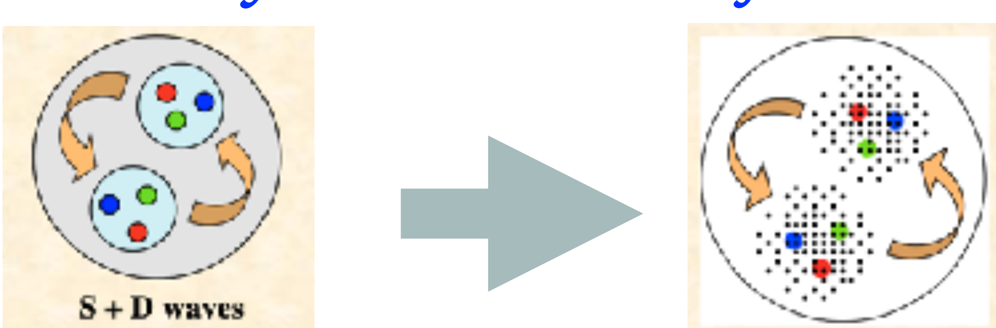


Spin crisis:

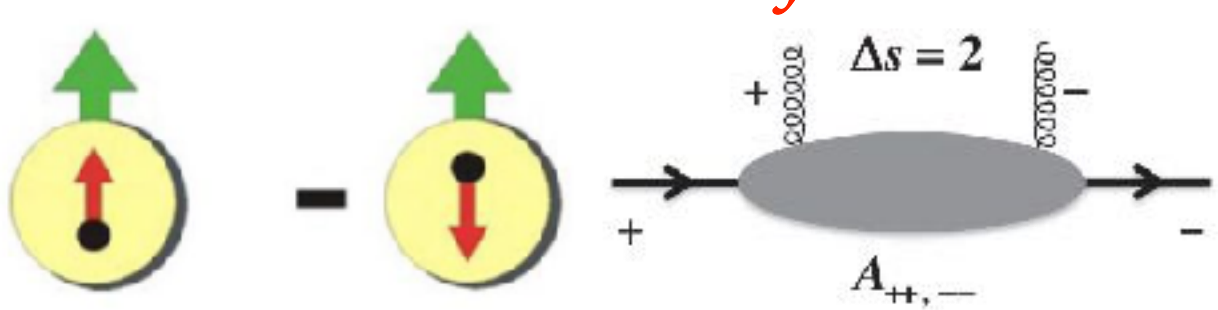
Gluon helicity



Nonbaryonic content of deuteron:

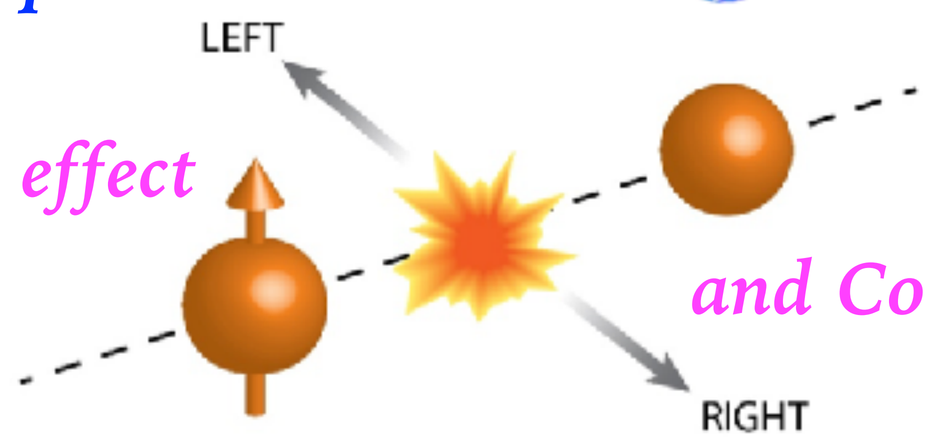


Gluon transversity



Gluon and quark TMD PDFs:

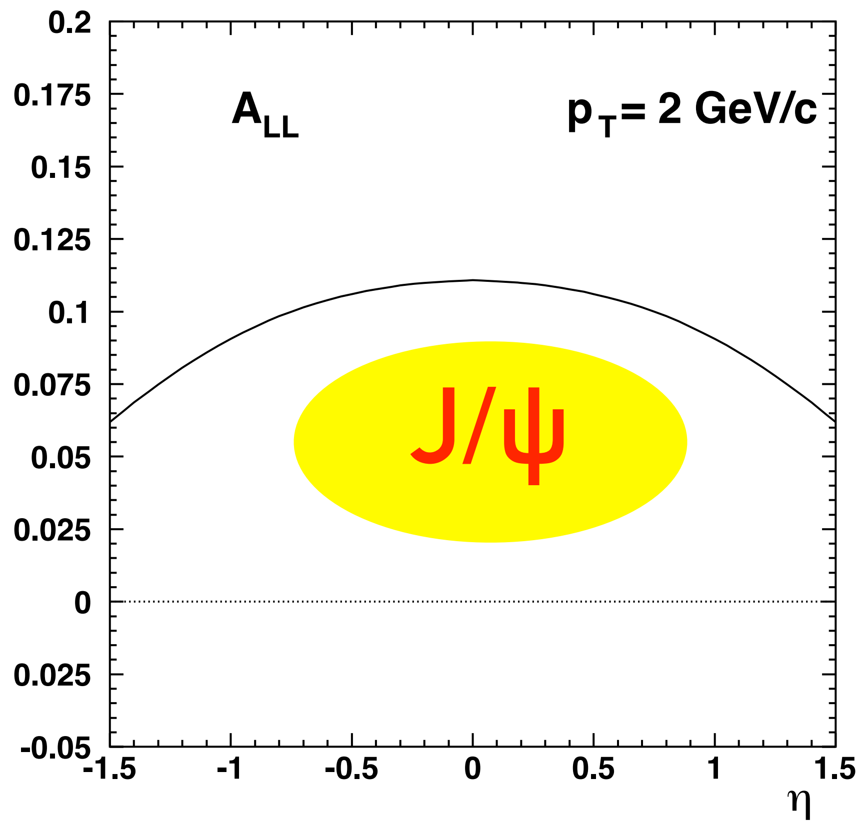
Sivers effect

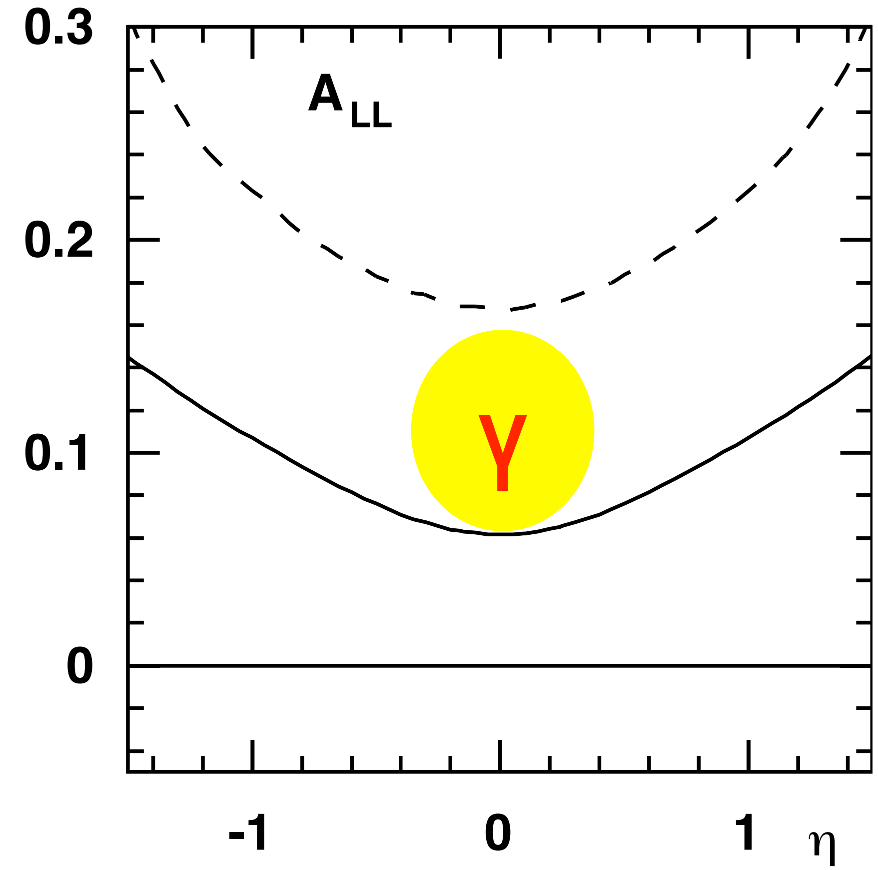


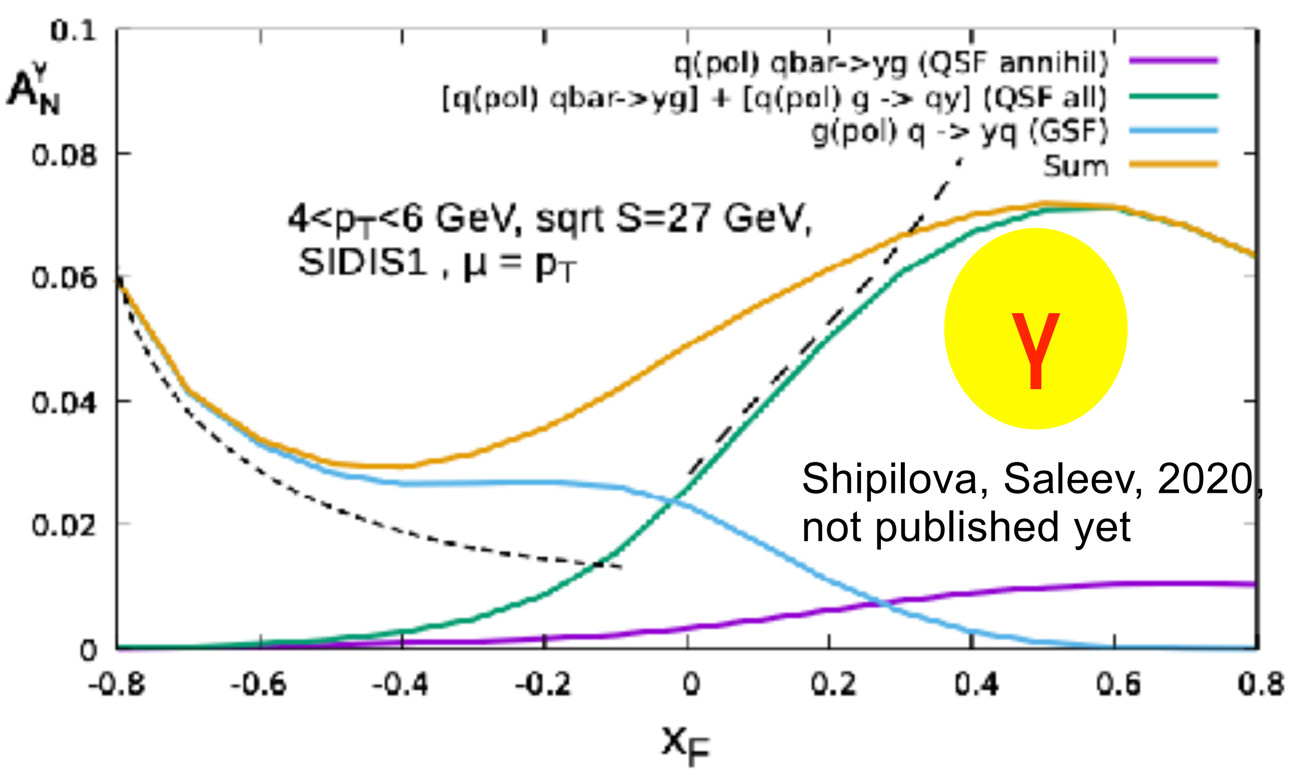
and Collins effect

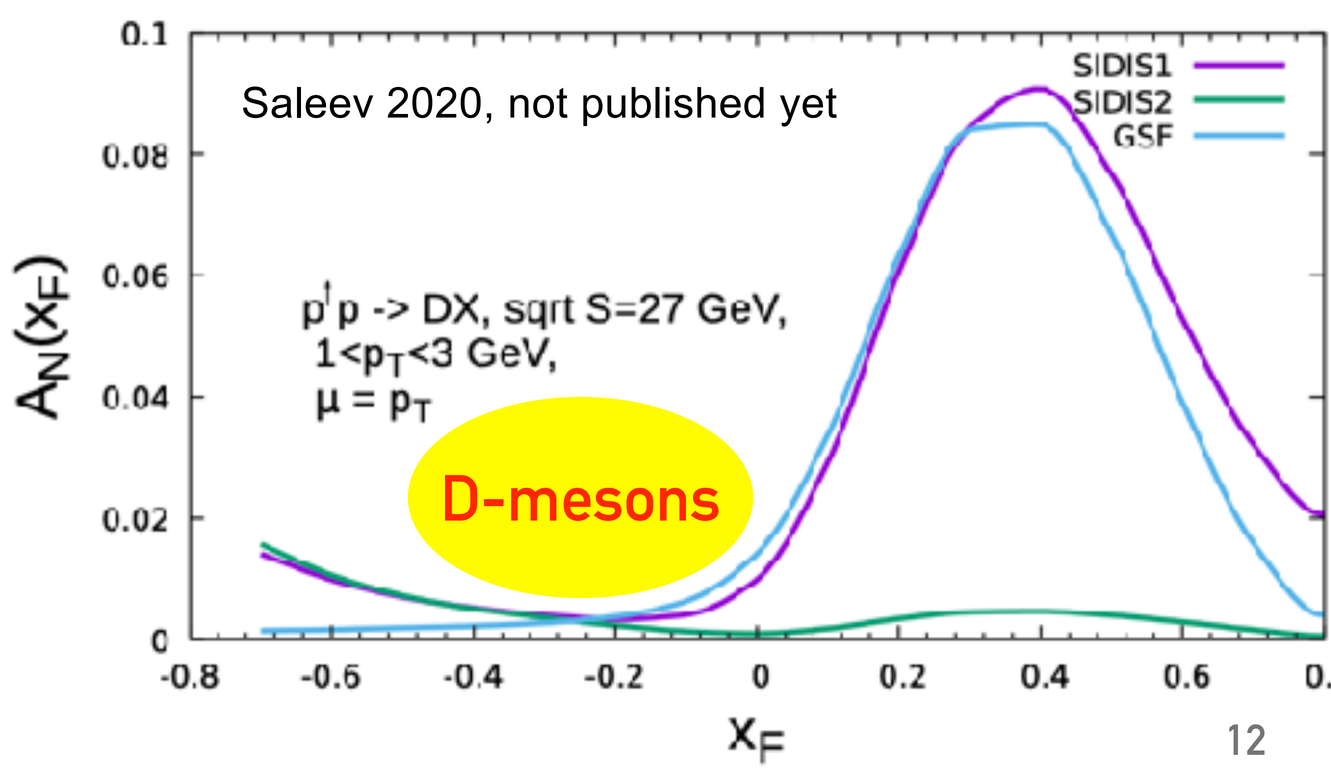
- *spin-dependent fragmentation functions*

EXPECTATIONS FOR SPD ENERGIES







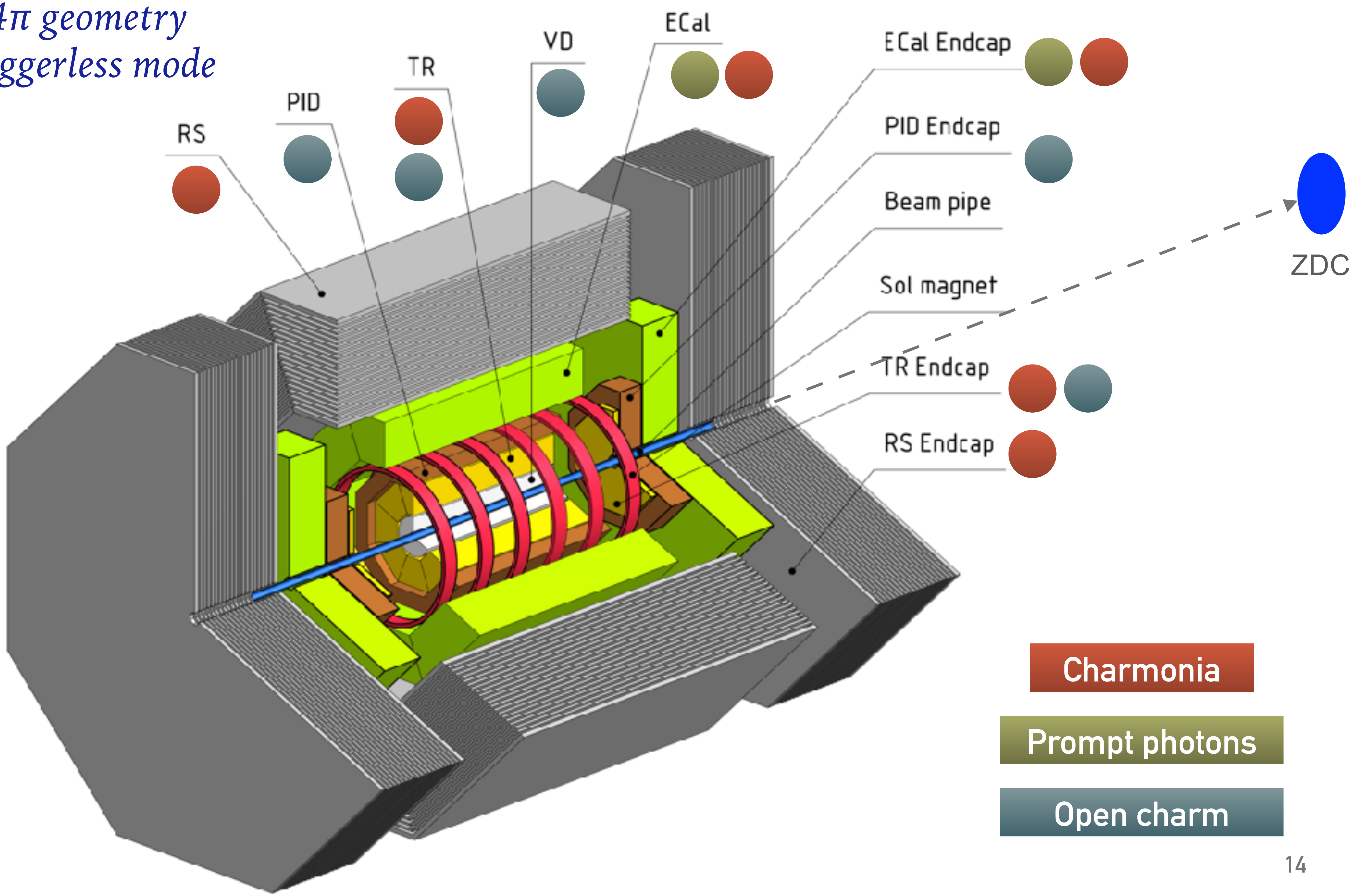


PHYSICS OF THE FIRST STAGE OF SPD RUNNING

- 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
- Auxiliary measurements for astrophysics
- …

WHAT SPD HAS FOR OPERATION WITH SUCH PROBES?

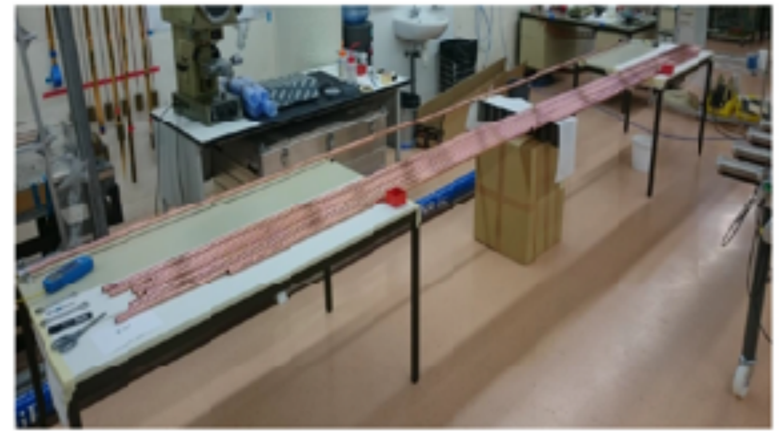
$\sim 4\pi$ geometry
Triggerless mode

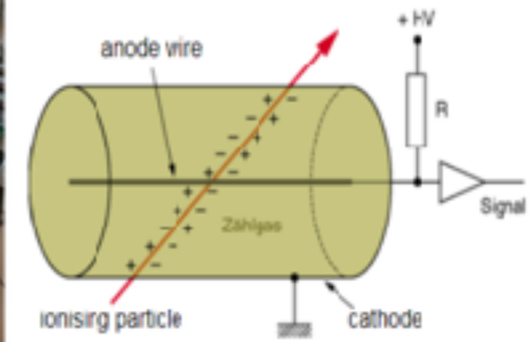


TRACKING

Straw tracker

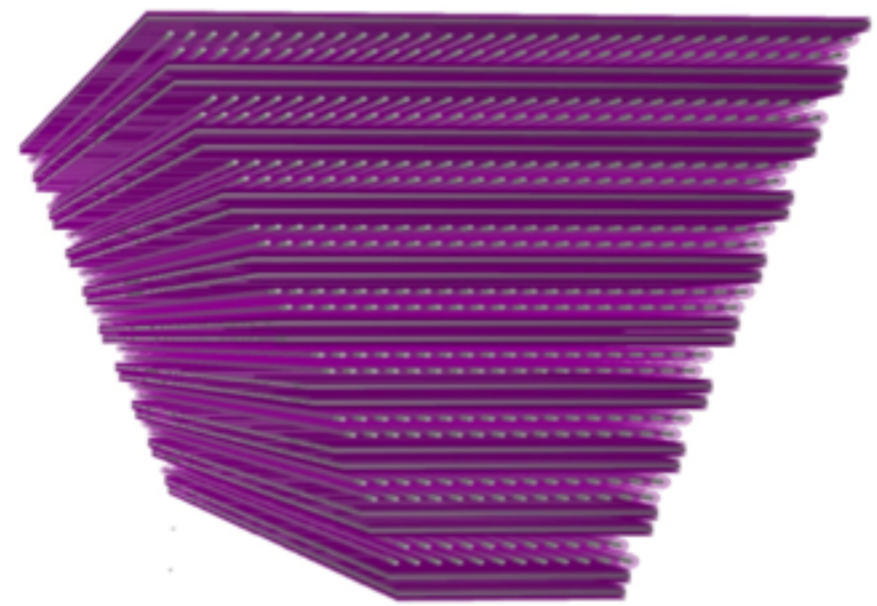
Magnetic field at the beam axis - 1 T



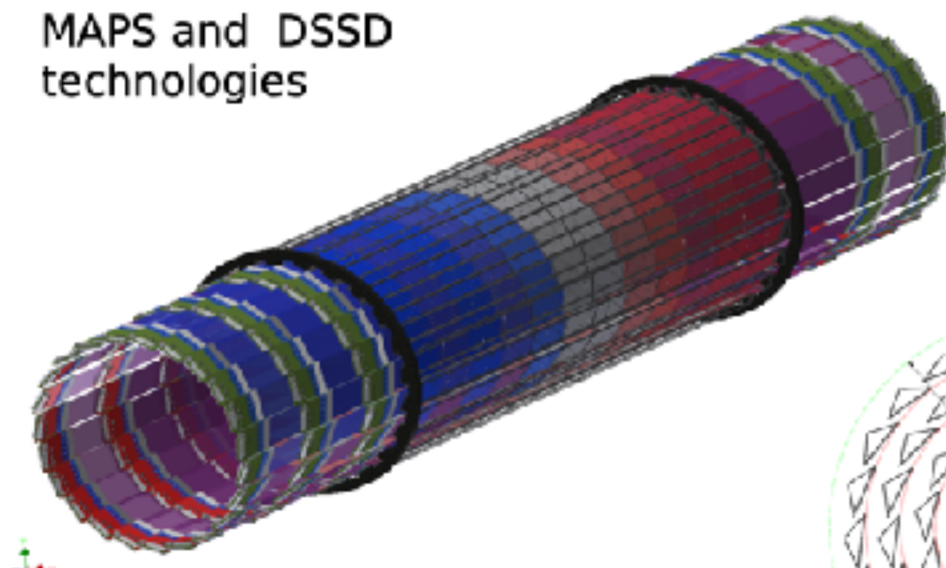


Silicon vertex detector

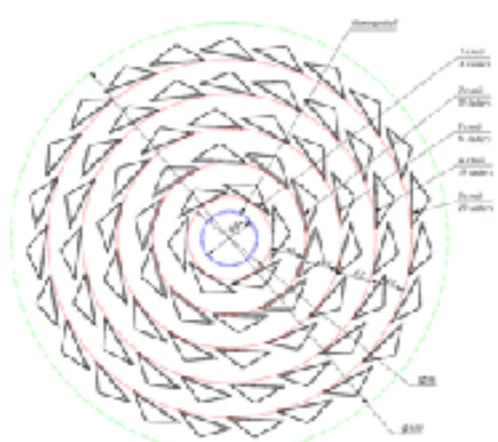
$\sigma_{J/\psi} \approx 40$ MeV



VD is based on the MAPS and DSSD technologies



3D view of Vertex Detector with silicon sensors, signal cables and FEE boards



View across the beam pipe

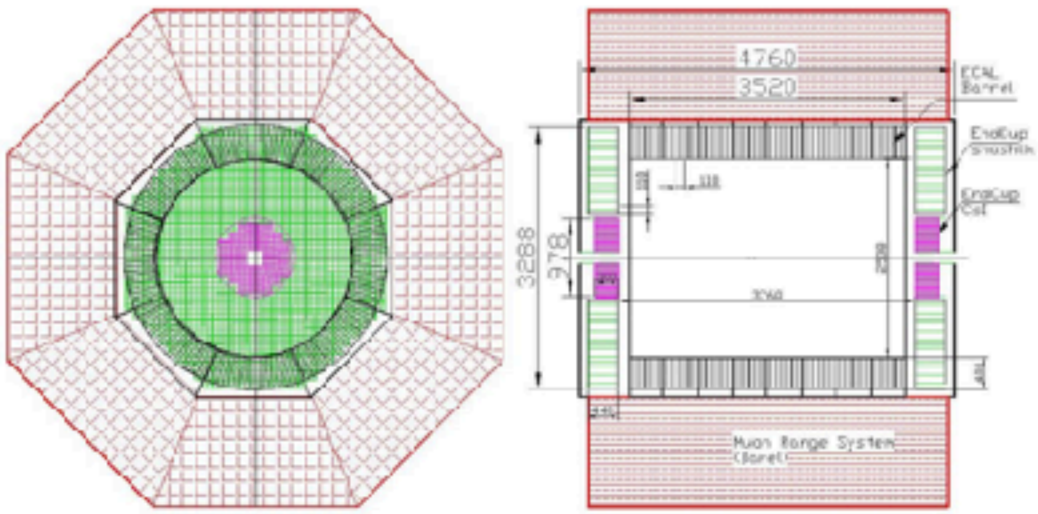
24 XY(optional UV) wedge-shaped straws stations

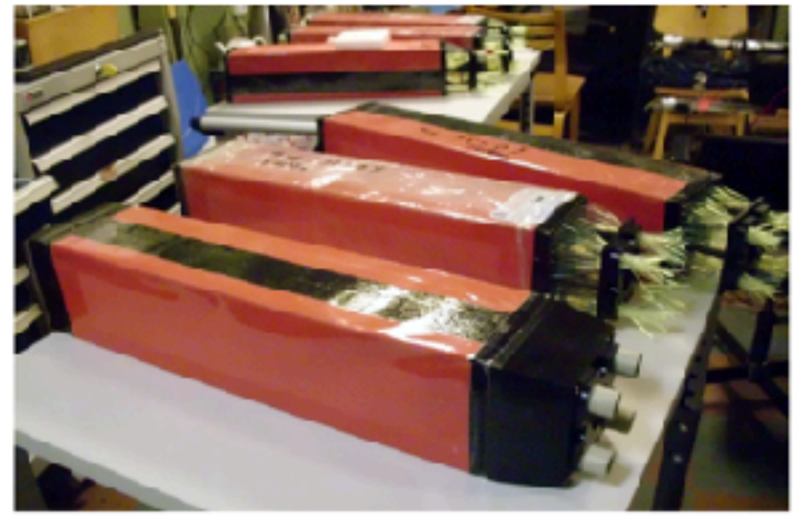
Straw tube with 10mm diameter, in the center a 30mkm diameter gold-plated tungsten wire

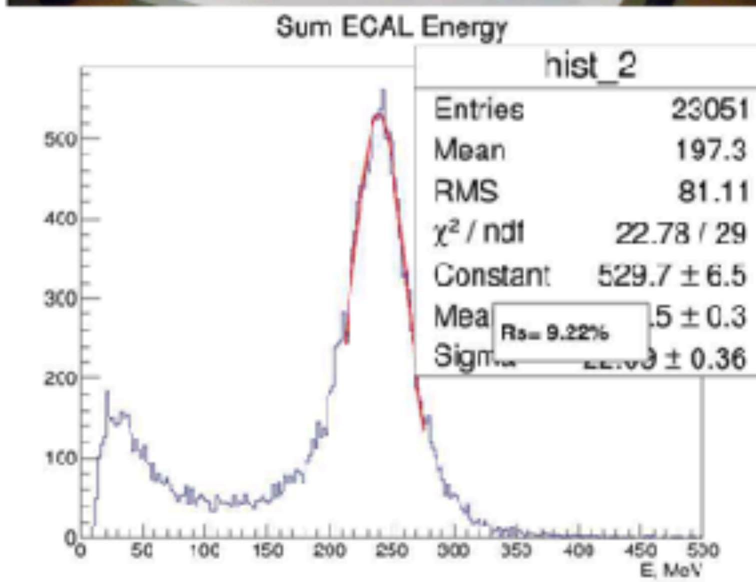
Precision measurement ~150 mkm

The number of layers and the number of straws are discussed.

CALORIMETRY







Cosmic test results (MIP)

Photon energy range 0.1 - 10 GeV.

Due to space limitations the total length of the ECAL module should be less than 50 cm.

Required energy resolution <5.0%/√E (GeV) and energy threshold below 100 MeV.

Design is "shashlyk" and crystal.

Projective geometry.

ECAL

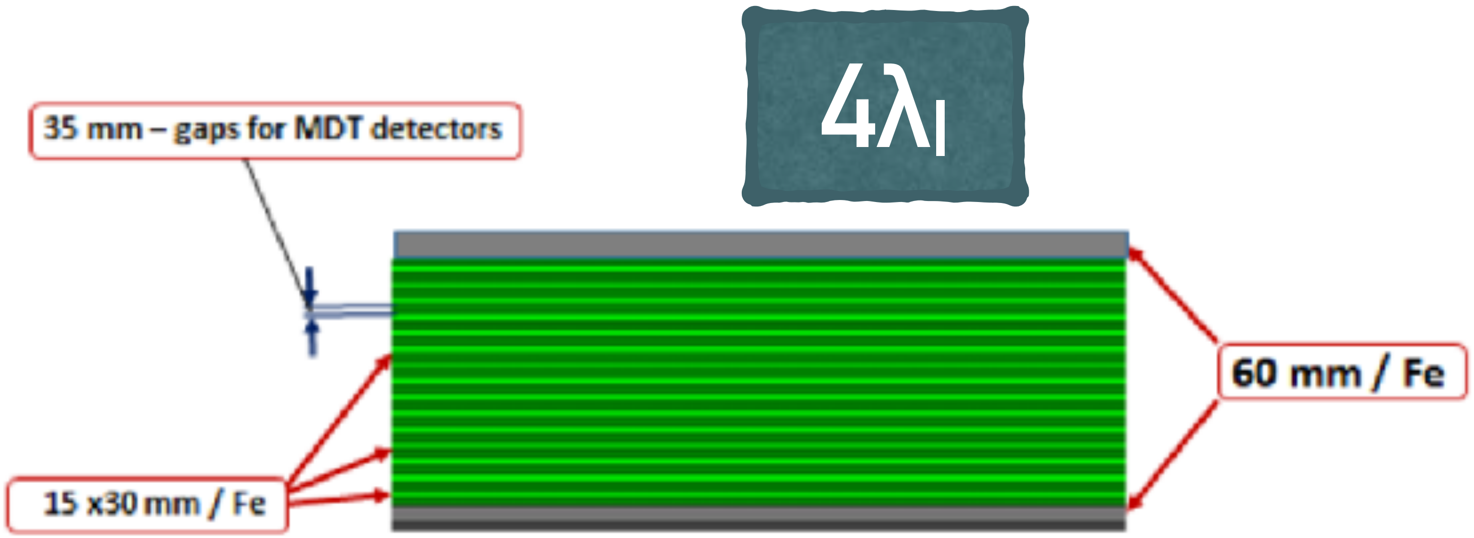
Threshold:

50-100 MeV

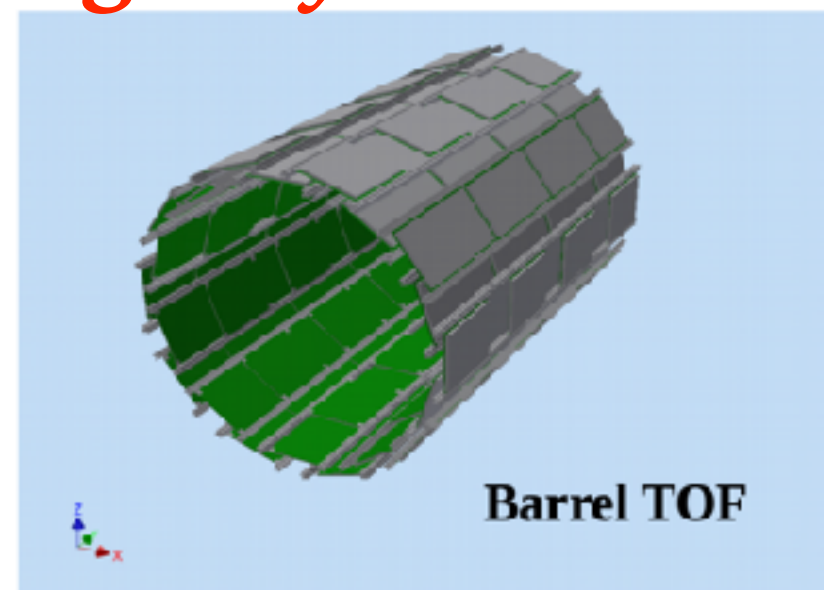
$$\sigma_E/E = 5\,\%/\sqrt{E} \oplus 2\,\%$$

PARTICLE IDENTIFICATION

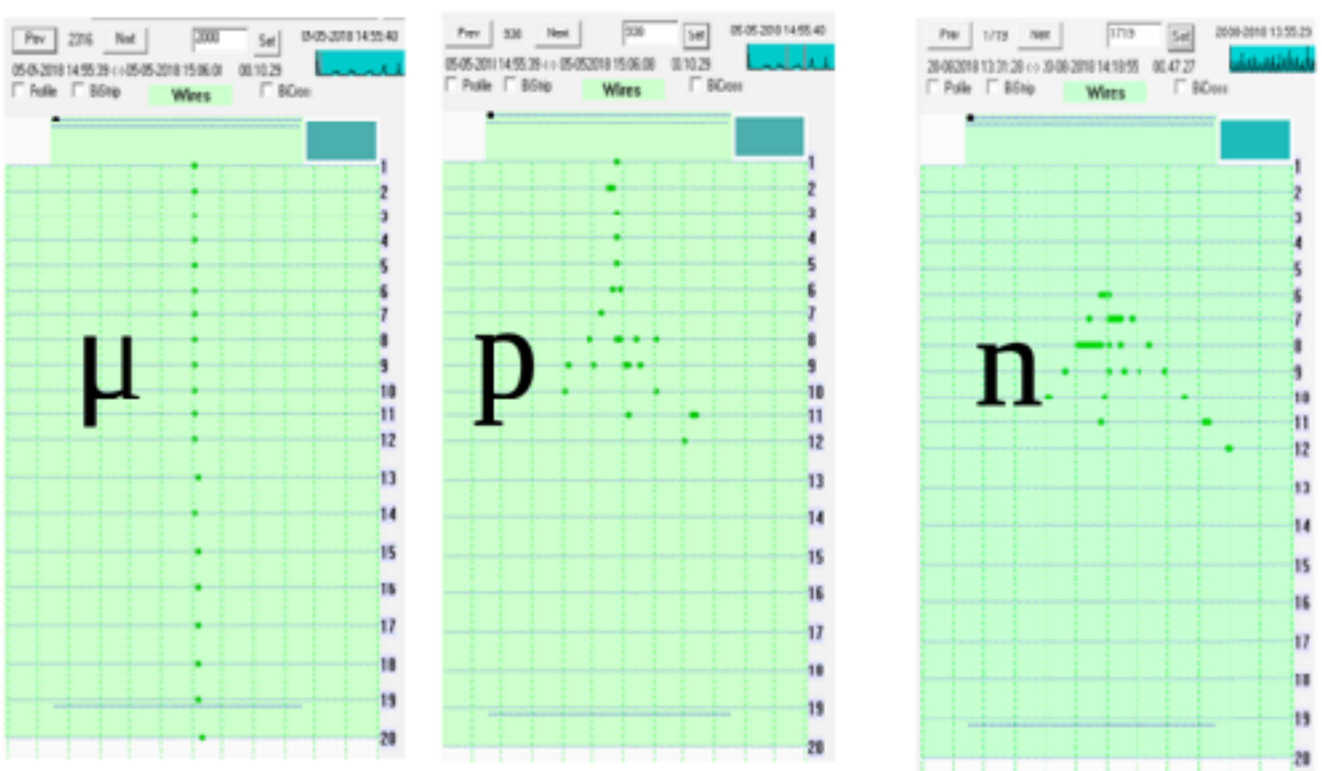
Muon (range system)

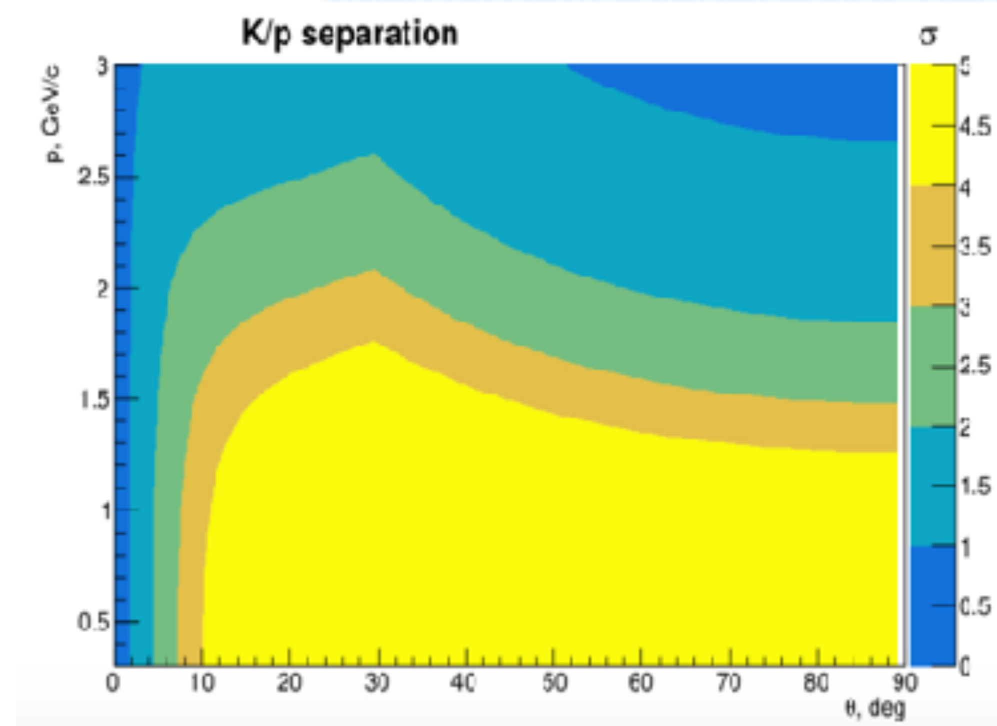


Time-of-flight system



Event examples at 5 GeV/c

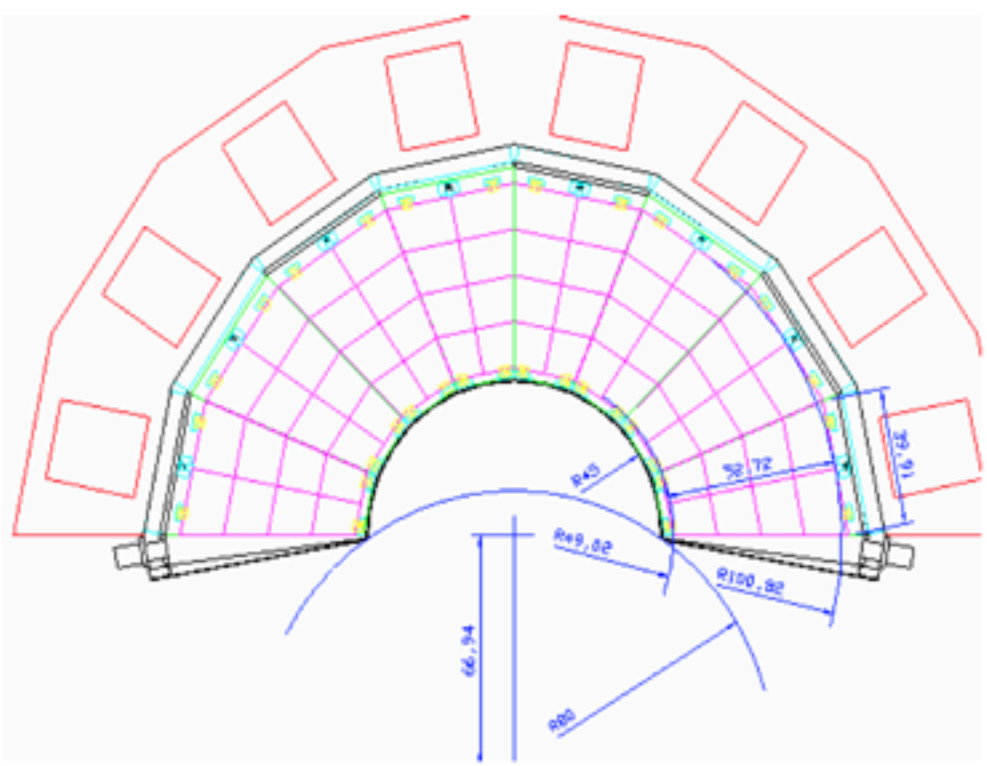




DIRC/aerogel as an option

POLARIMETRY AND LUMINOSITY MONITORS

Beam-beam counter

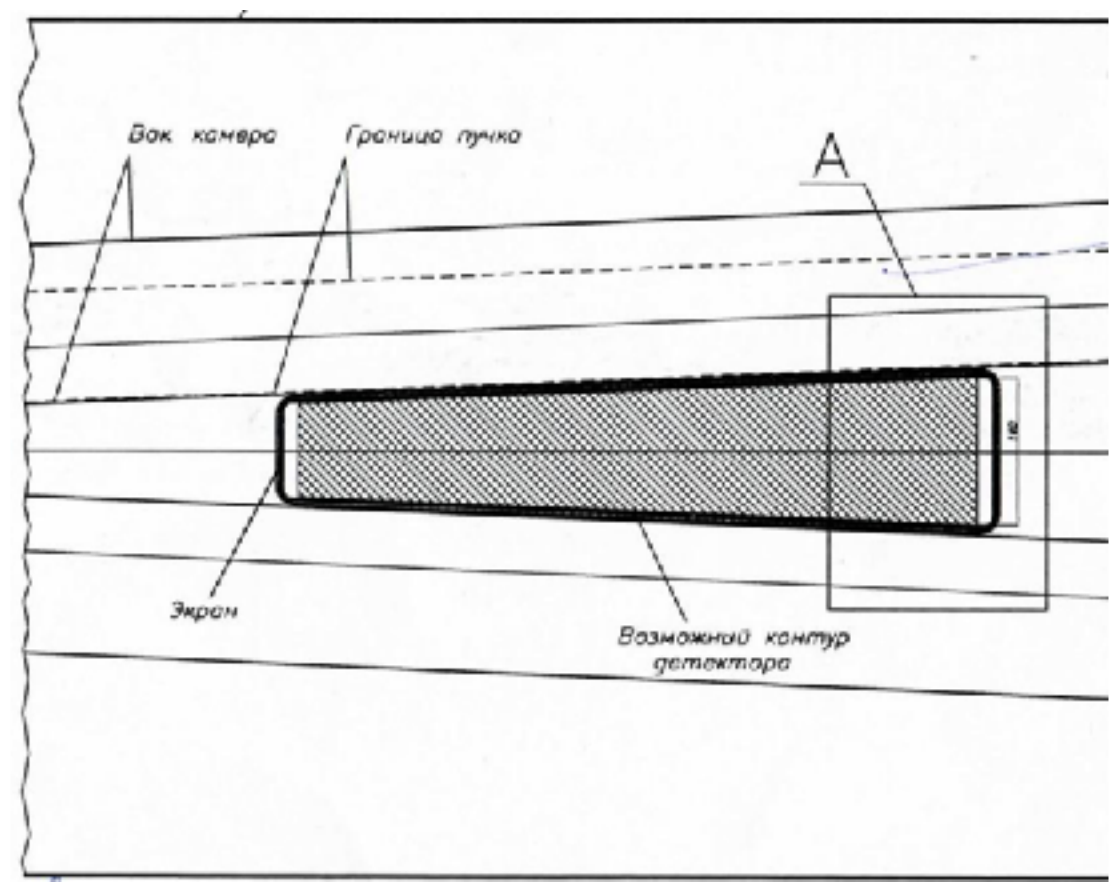


Concept:

inner part – microchannel plates (MCP) based detectors

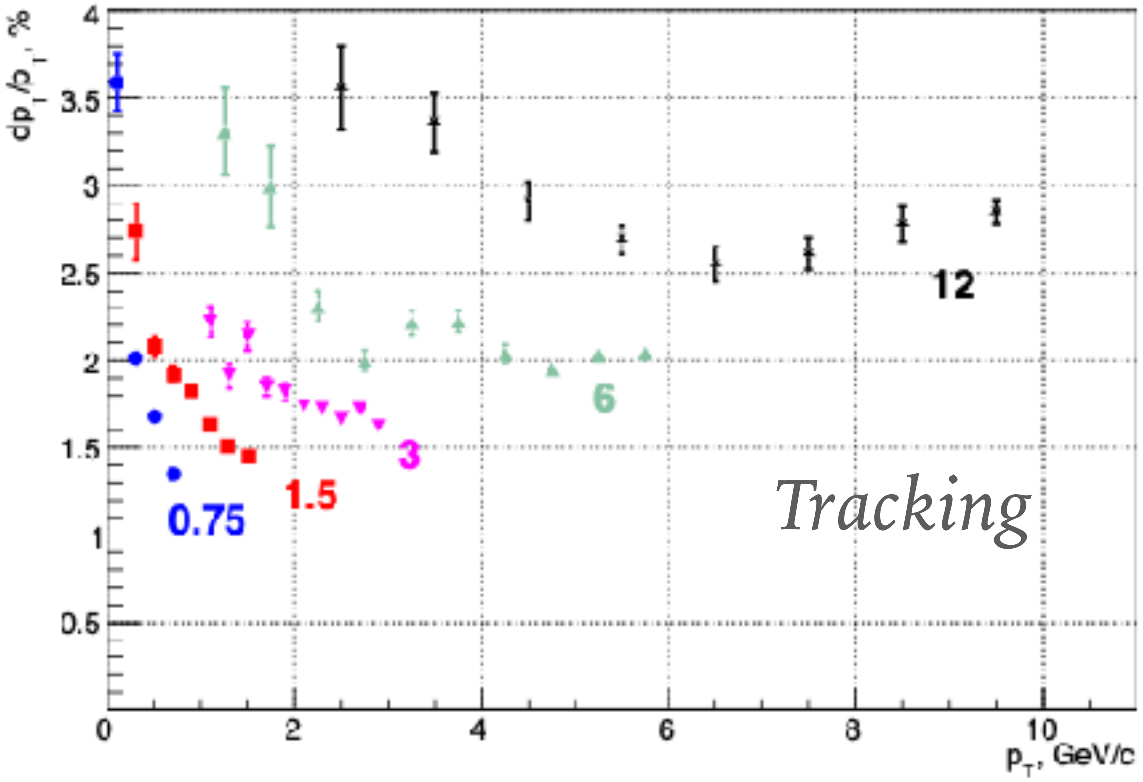
outer part - high granularity scintillator tiles with SIPM readout

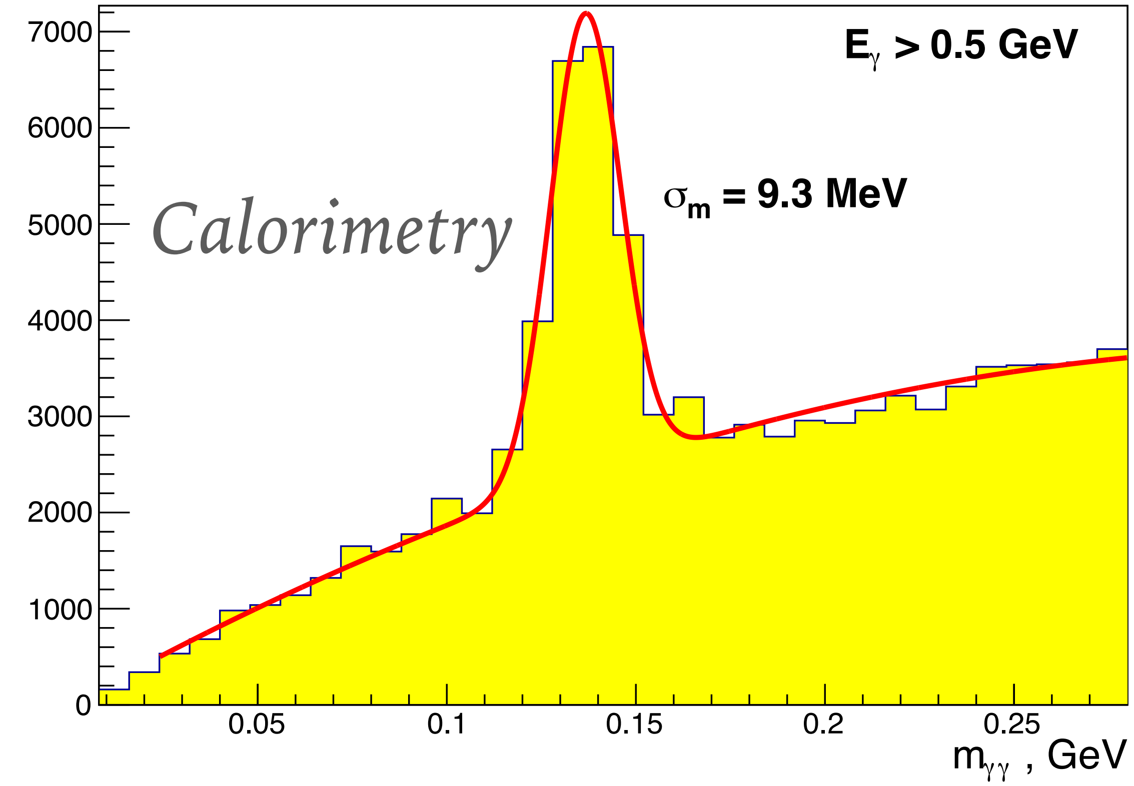
Zero degree calorimeter

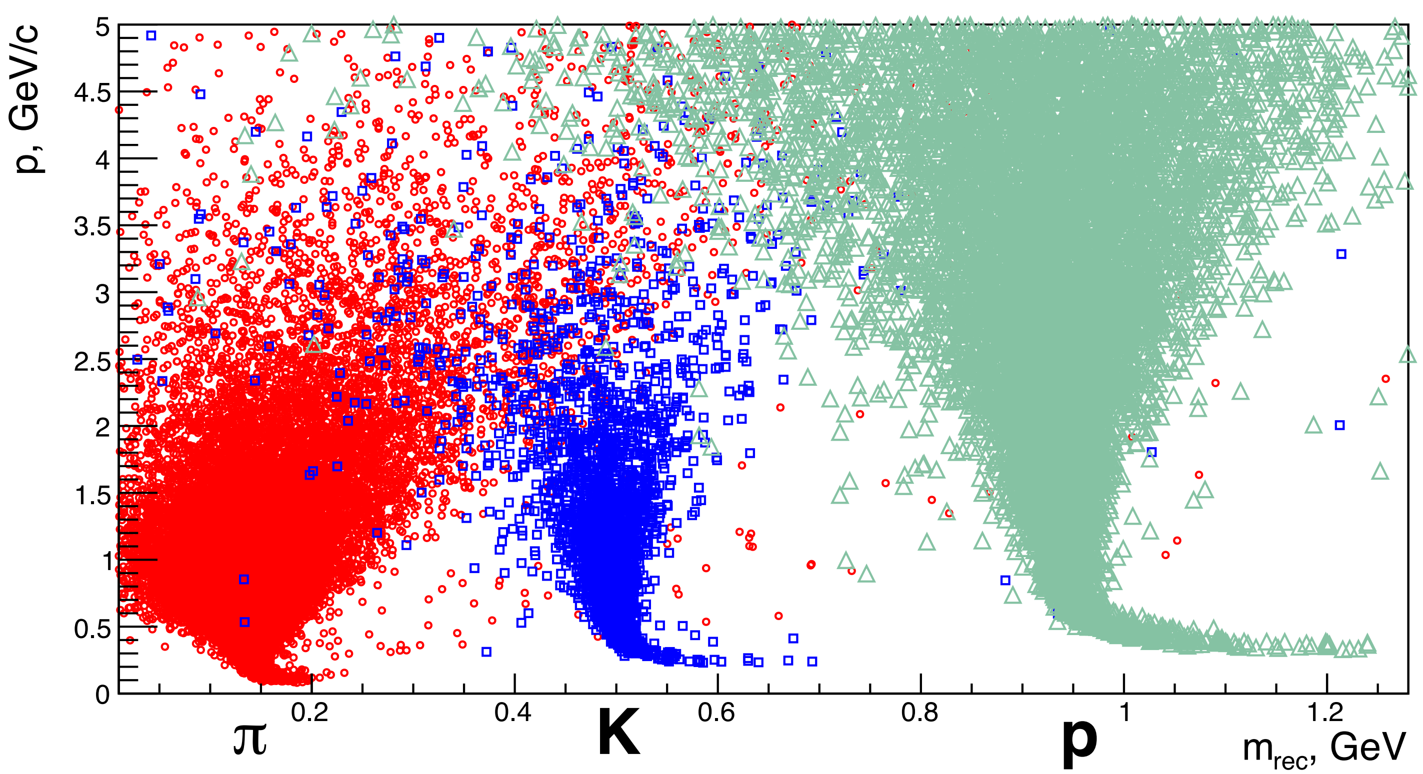


Neutron detector and luminosity monitor

EXPECTED PERFORMANCE







PARTICIPANTS OF THE SPD PROJECT

- ✓ National Science Laboratory, Armenia
- ✓ Institute of Applied Physics of the Belarus Academy of Sciences;
- Gomel State Technical University, Belarus;
- Institute for Nuclear Problems of BSU – Minsk;
- Chilean cluster of universities, Chile
- Tsinghua University, Tsinghua, China
- Instituto Superior de Tecnologías y Ciencias Aplicadas (INsTEC), Havana University;
- ✓ Charles University, Prague;
- ✓ Technical University, Prague
- INFN section of Turin and University of Turin;
- CEA, Saclay, France;
- ✓ Warsaw University of Technology;
- ✓ Tomsk State University;
- Tomsk Polytechnic University;
- ✓ Lebedev Physics Institute of the RAS, Moscow;
- ✓ Institute for High Energy Physics, Protvino;
- ✓ Institute of Nuclear Physics of the Moscow State University;
- Institute for Nuclear Research of the RAS, Troitsk;
- ✓ Institute for Theoretical and Experimental Physics, Moscow;
- St. Petersburg Nuclear Physics Institute, Gatchina;
- St. Petersburg State University;
- St. Petersburg Polytechnic University;
- ✓ Samara National Research University;
- ✓ Belgorod National Research University;
- Kharkov National University, *Kharkov, Ukraine*

Protocols for joint research within the SPD project signed.

✓ EoI letters received

Bilateral agreements on NICA exist.

List is permanently growing

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.
- **The SPD gluon physics program is complementary to the other intentions to study the gluon content of nuclei (RHIC, AFTER, LHCspin, EIC) and mesons (COMPASS++/AMBER, EIC).**
- **The physics program for the first stage of SPD operation is also under preparation**
- **The SPD project is opened for new ideas and collaborators. There is a plenty of directions for our collaboration: physics, detectors, computing etc. More detailed information could be found in the following talks.**