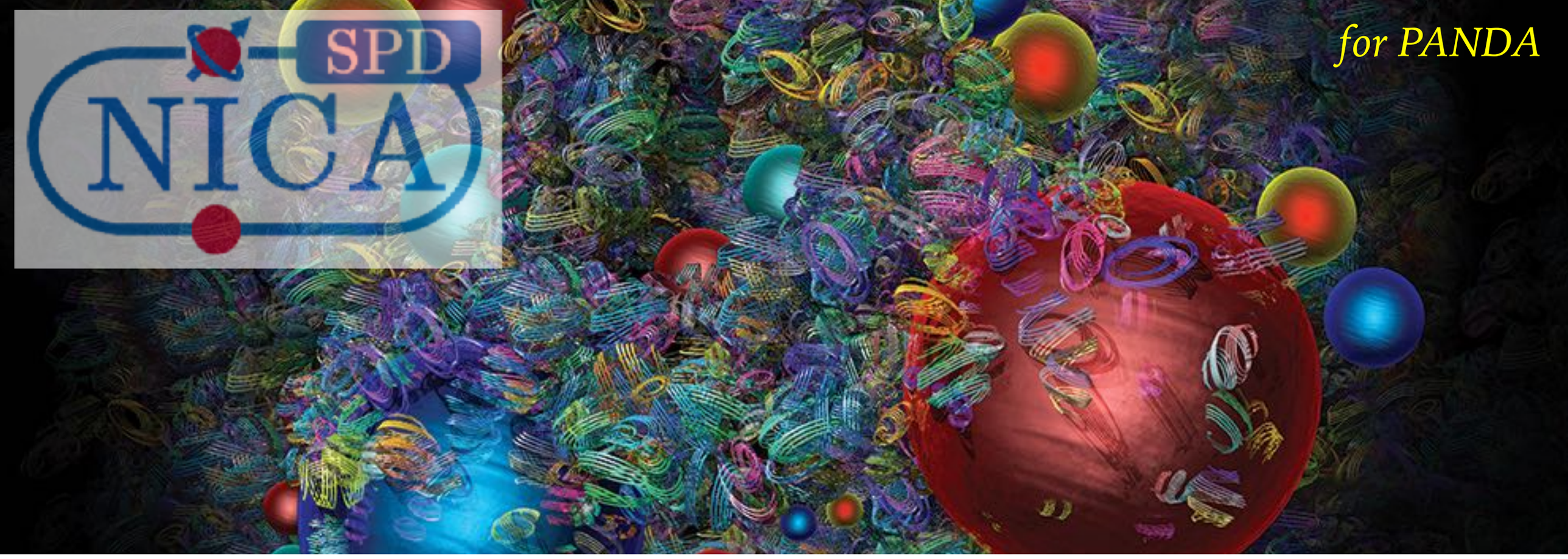


SPIN PHYSICS DETECTOR PROJECT AT NICA COLLIDER

Alexey Guskov, JINR

Alexey.Guskov@cern.ch

22.6.21

SPD AT NICA

NICA - Nuclotron-based Ion Collider fAcility

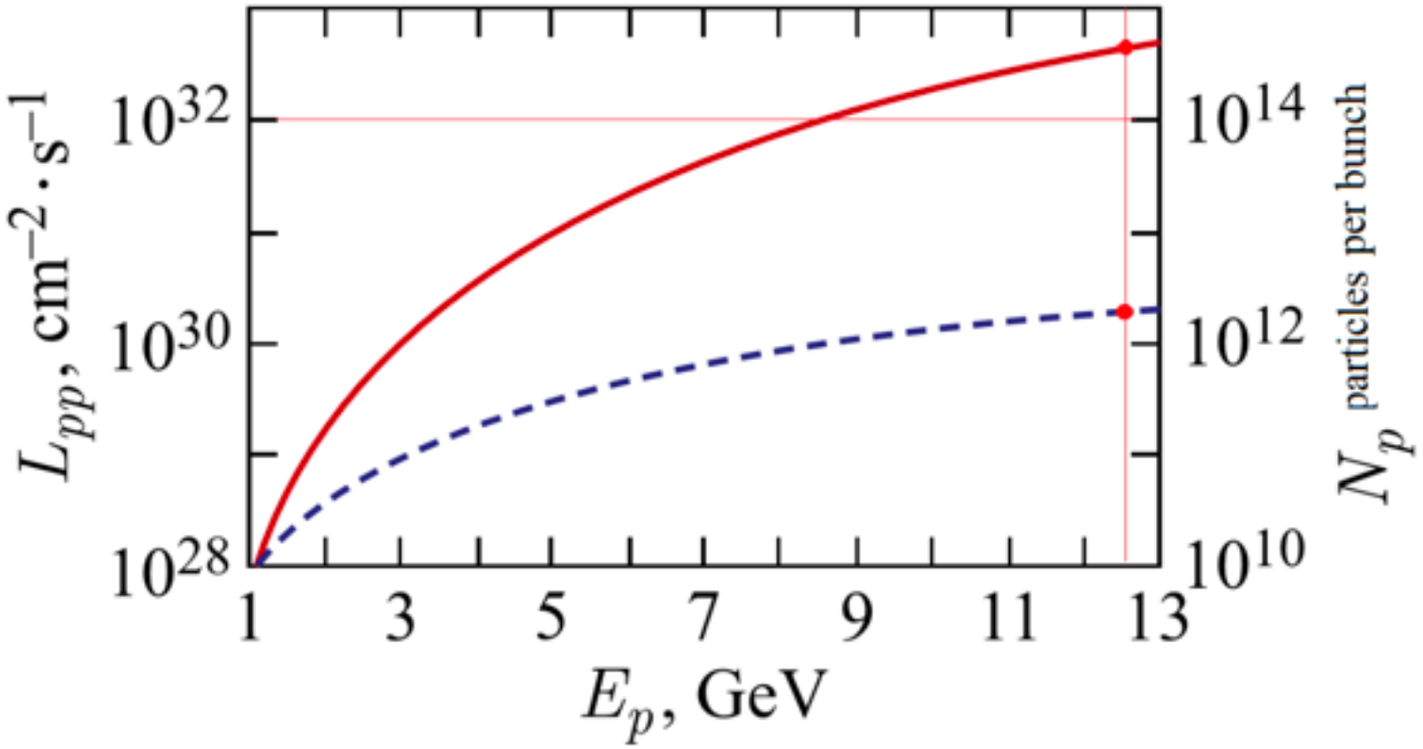
$p^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 27\ GeV$

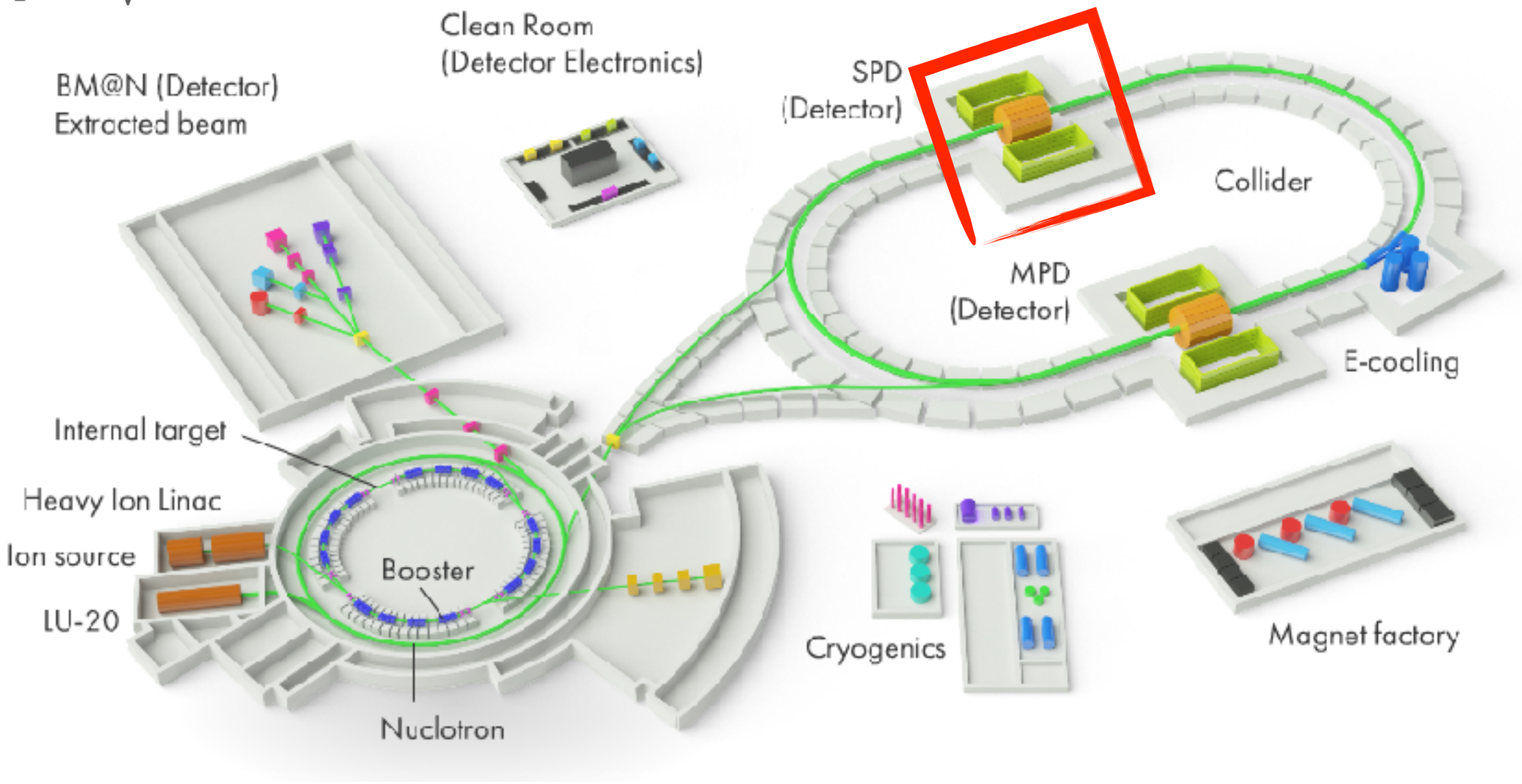
$d^{\uparrow}d^{\uparrow} : \sqrt{s} \leq 13.5\ GeV$

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

U, L, T

|P|>70%





503 m

POLARIZED BEAMS AT NICA

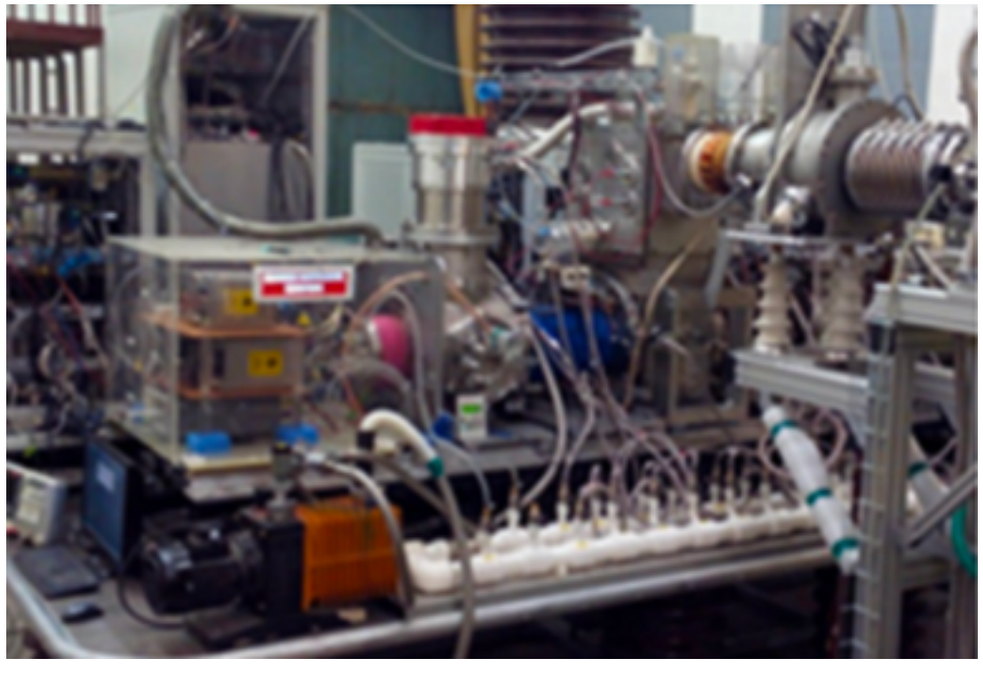
d↑- was accelerated in 1986 (Synchrophasotron) and 2002 (Nuclotron). It is quite simple procedure: there is just 1 depolarizing spin resonance at 5.6 GeV.

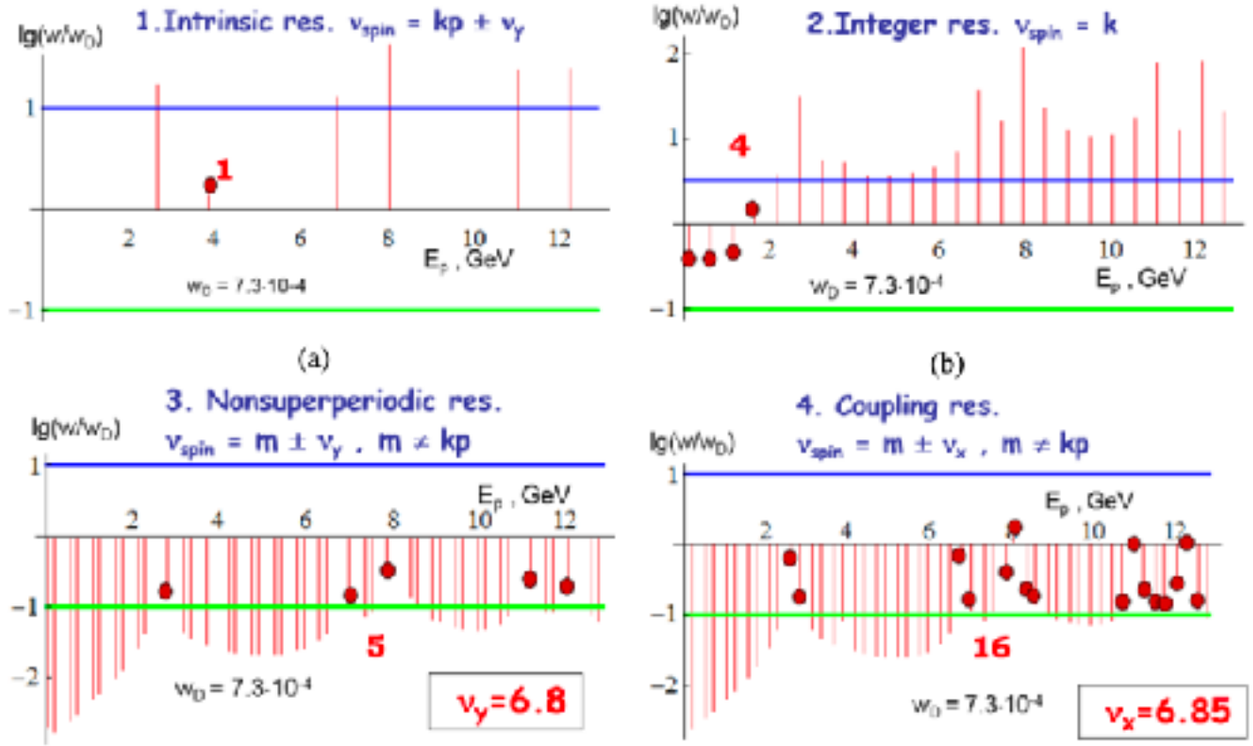
p↑- was first obtained only in 2017.

Source of Polarized Ions:

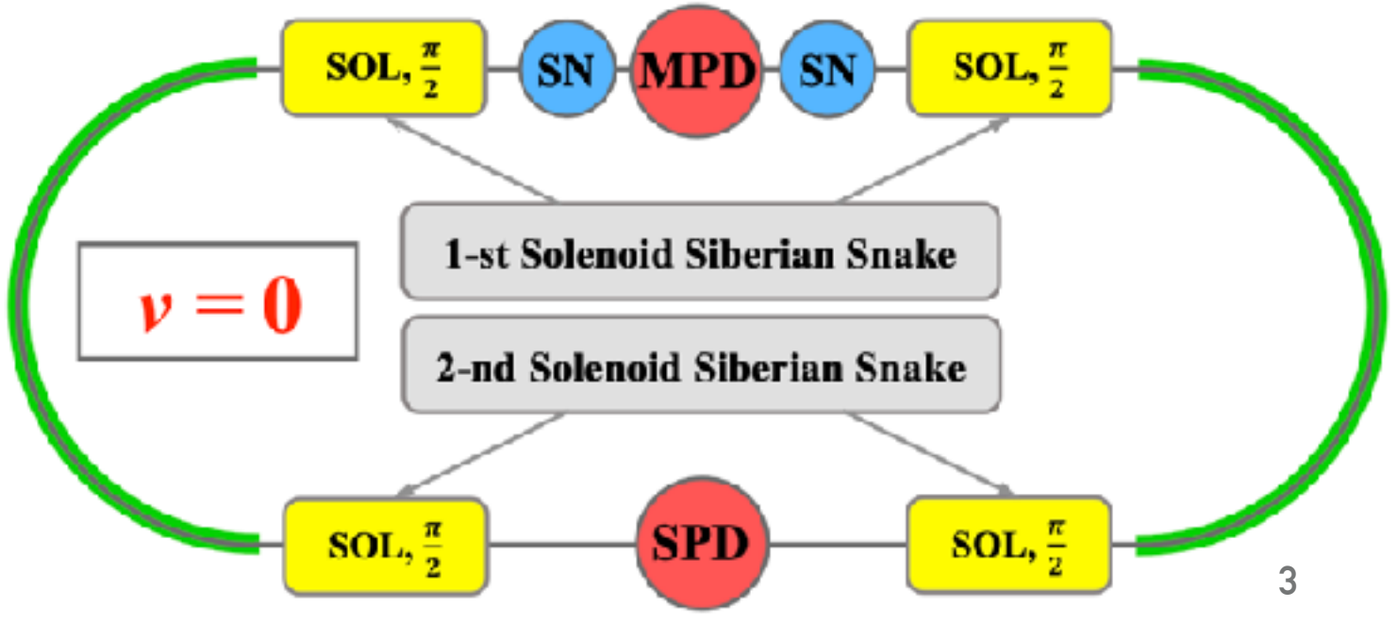
$$H^0 \uparrow + D^+ \rightarrow H^+ \uparrow + D^0$$

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





Spin Transparency mode for NICA ring




MPD
SPD

SPD INTERNATIONAL COLLABORATION

32 institutes from 14 states, ~300 members

The SPD international collaboration is forming actively

June, 4 -
birthday of the SPD collaboration

BRIEF HISTORY OF THE SPD PROJECT

2006: Idea of spin measurements at NICA

2014: SPD Letter of intent

Jan 2019: SPD project approved at JINR

June 2019: proto-collaboration meeting in Dubna

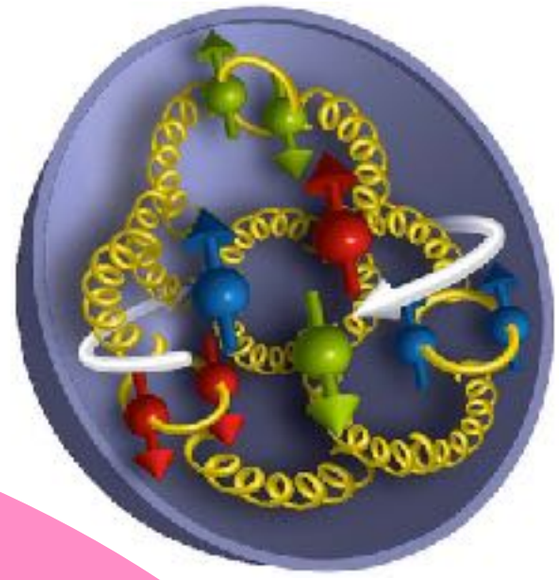
Jan 2021: SPD CDR

June 4, 2021: birthday of the SPD collaboration

Jul 2018: SPD workshop in Prague

Sep 2020: two remote SPD workshops

CONCEPT OF THE SPD PHYSICS PROGRAM



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

Charmonia

Prompt photons

Open charm

Other spin-related phenomena

Other physics

SPD Physics Program

JPPNP: 103858 | Model 3G | pp. 1–43 (col. fig: NIL)

ARTICLE IN PRESS

Progress in Particle and Nuclear Physics xxx (xxxx) xxx

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
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[h] INFN Sezione di Cagliari, I-09042 Monserrato, Italy

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

arXiv:2011.15005

SPD Physics Program

Prepared for Physics of Elementary Particles and Atomic Nuclei. Theory

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

arXiv:2102.08477

SPD Conceptual Design Report

CDR was presented on the meeting of the JINR Program Advisory Committee for particle physics on Jan, 18

JOINT INSTITUTE FOR NUCLEAR RESEARCH

February 3, 2021

Conceptual design of the Spin Physics Detector

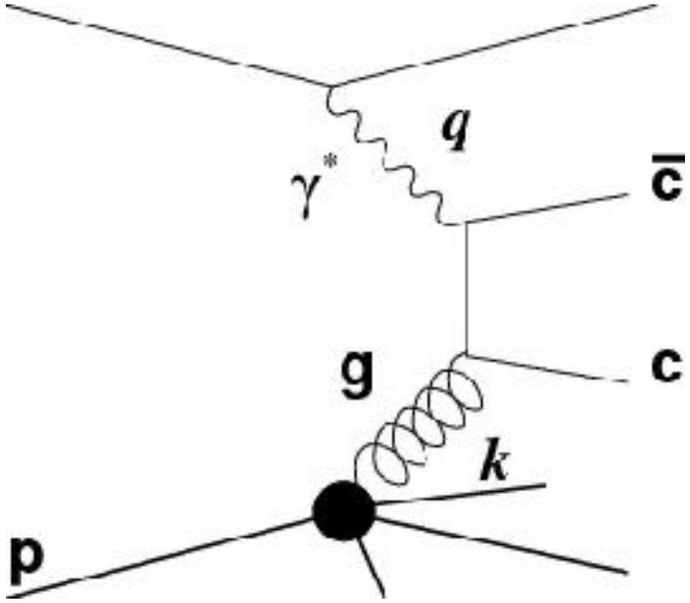
Version 1.0

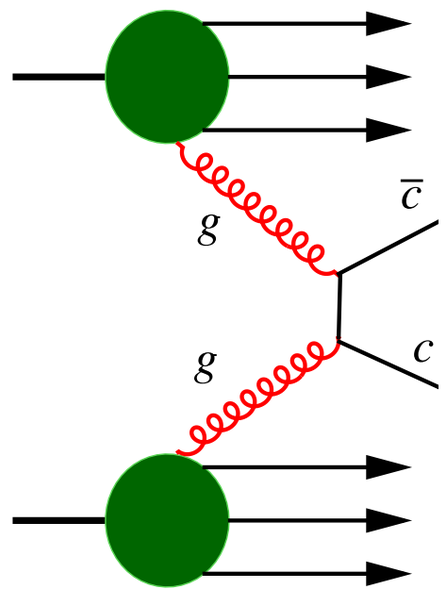
The SPD proto-collaboration*

arXiv:2102.00442

WHY GLUONS?

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



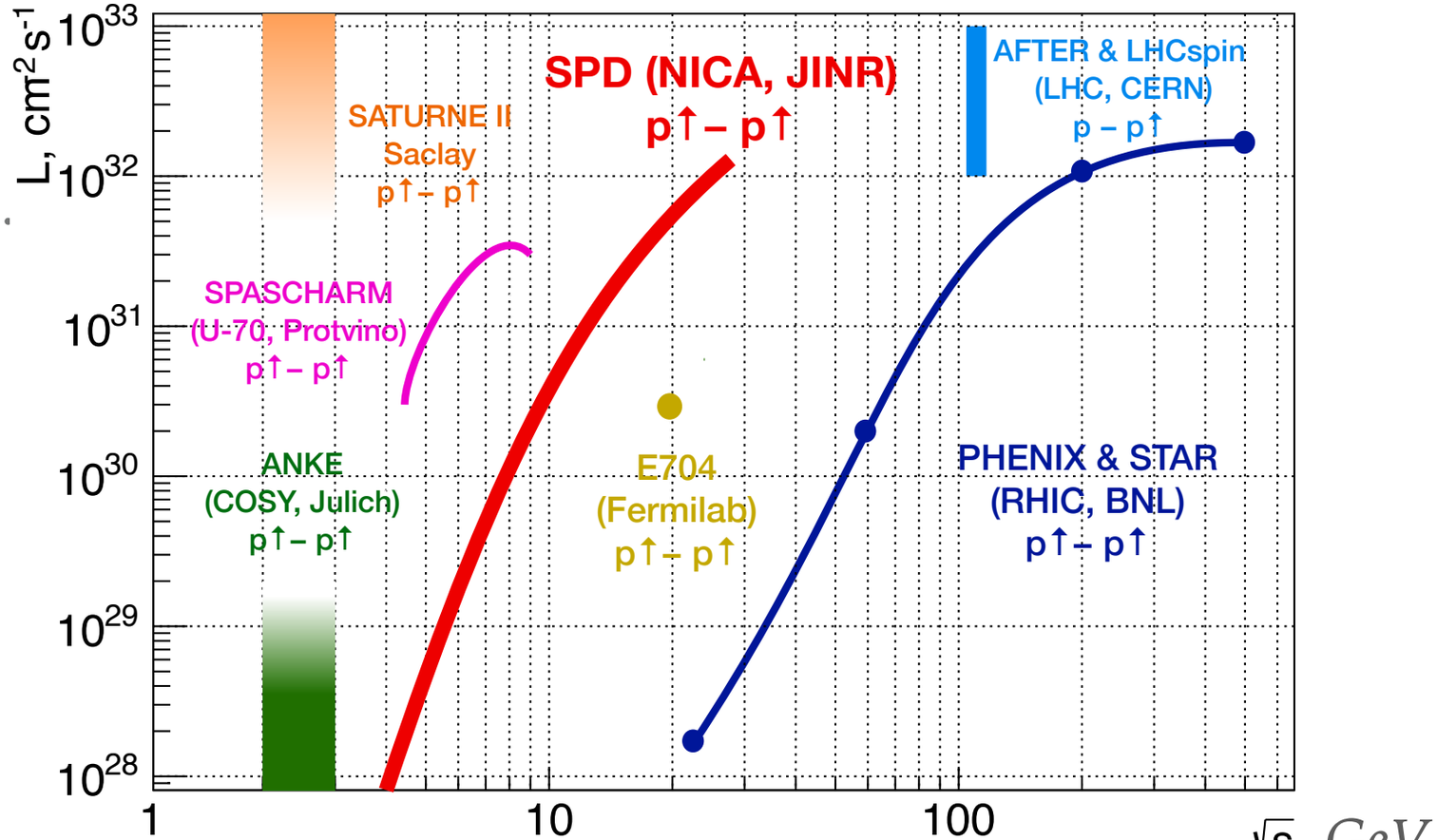


SIDIS ***Hadroproduction***

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

SPD – VS OTHERS

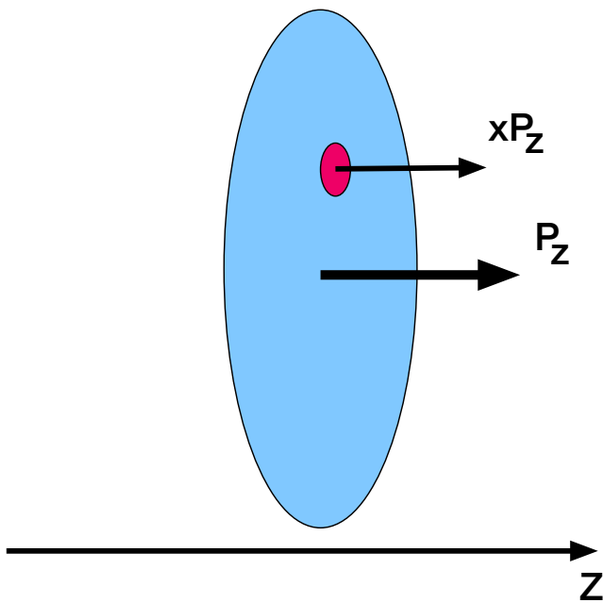
In the $p^{\uparrow}p^{\uparrow}$ mode:



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

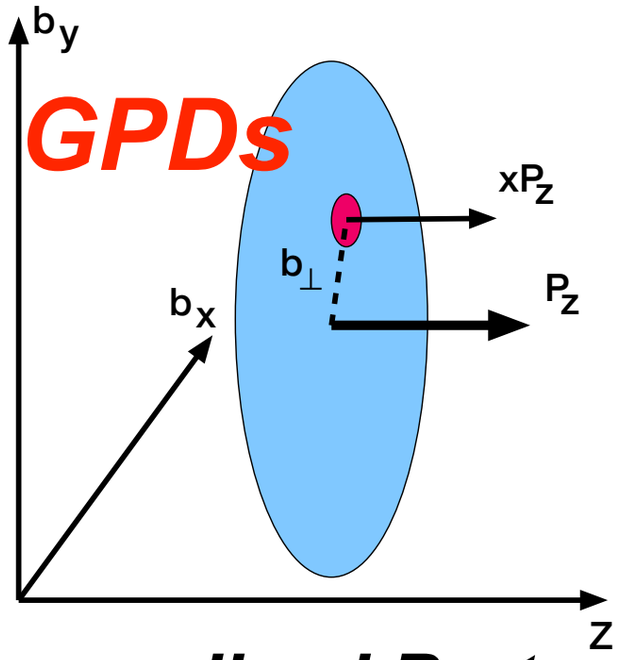
In the $d^{\uparrow}d^{\uparrow}$ mode we are unique

3D STRUCTURE OF THE PROTON

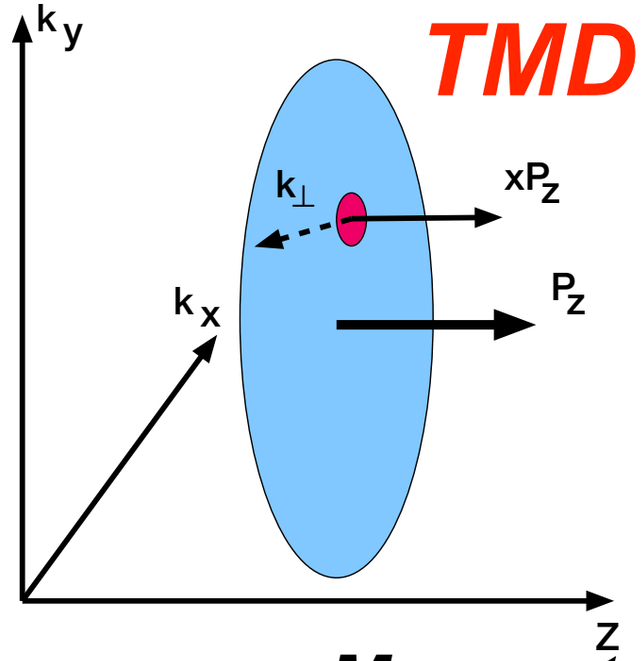


Collinear approximation

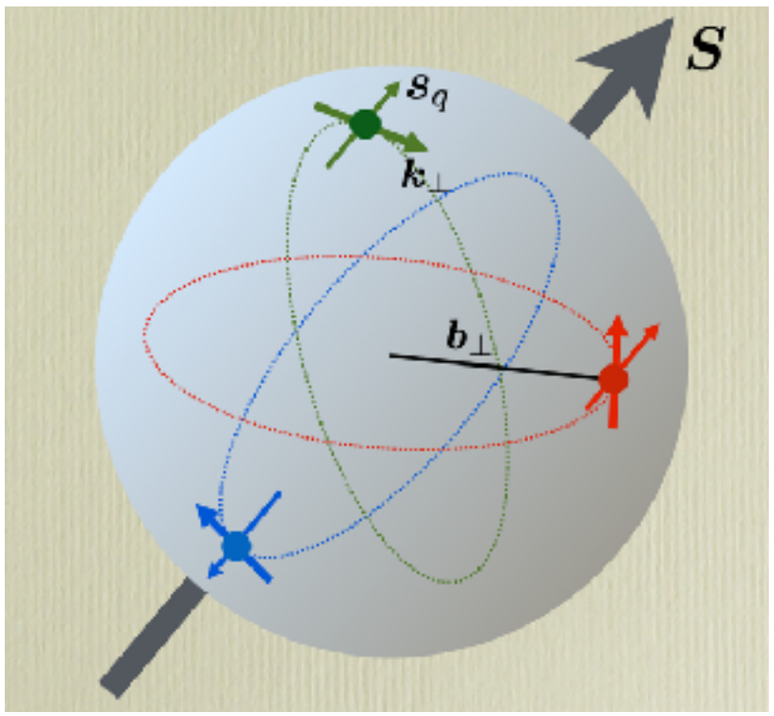
(common PDF)



Generalized Parton Distributions



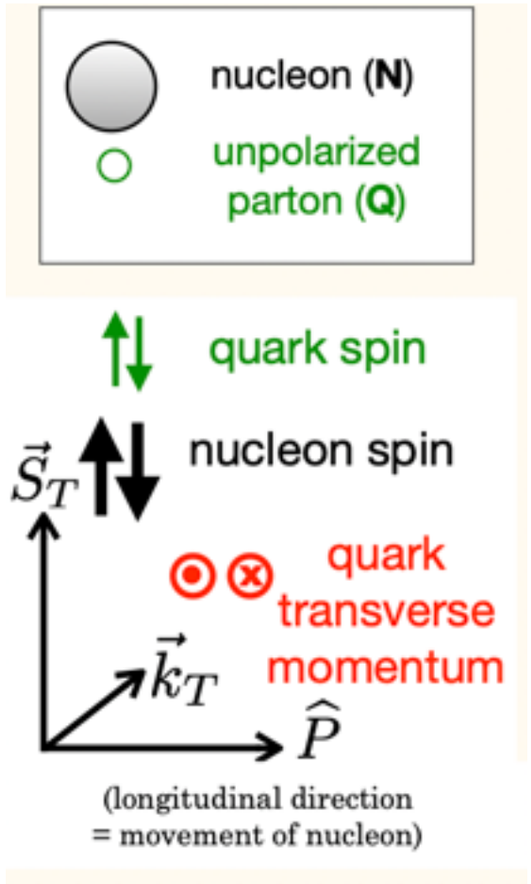
Transverse Momentum Dependent PDFs

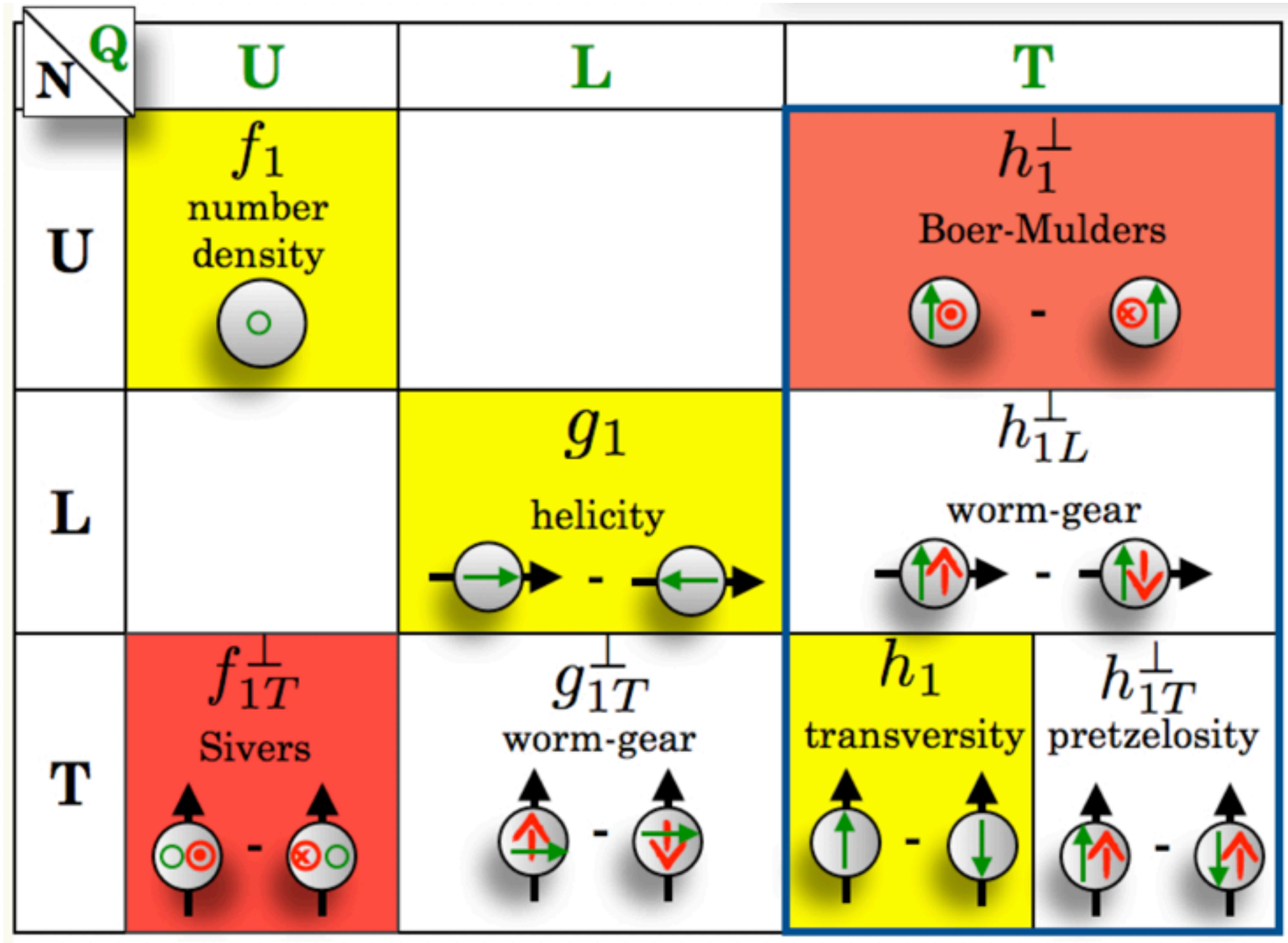


3D structure of nucleon

connection to orbital moment

TMD PDFS


nucleon (N)
unpolarized parton (Q)
quark spin
nucleon spin
$\vec{S}_T$
quark transverse momentum
$\vec{k}_T$
$\hat{P}$
(longitudinal direction = movement of 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 PDFs

arXiv:2011.15005

Unpolarized gluons at high x in proton and deuteron

Gluon helicity

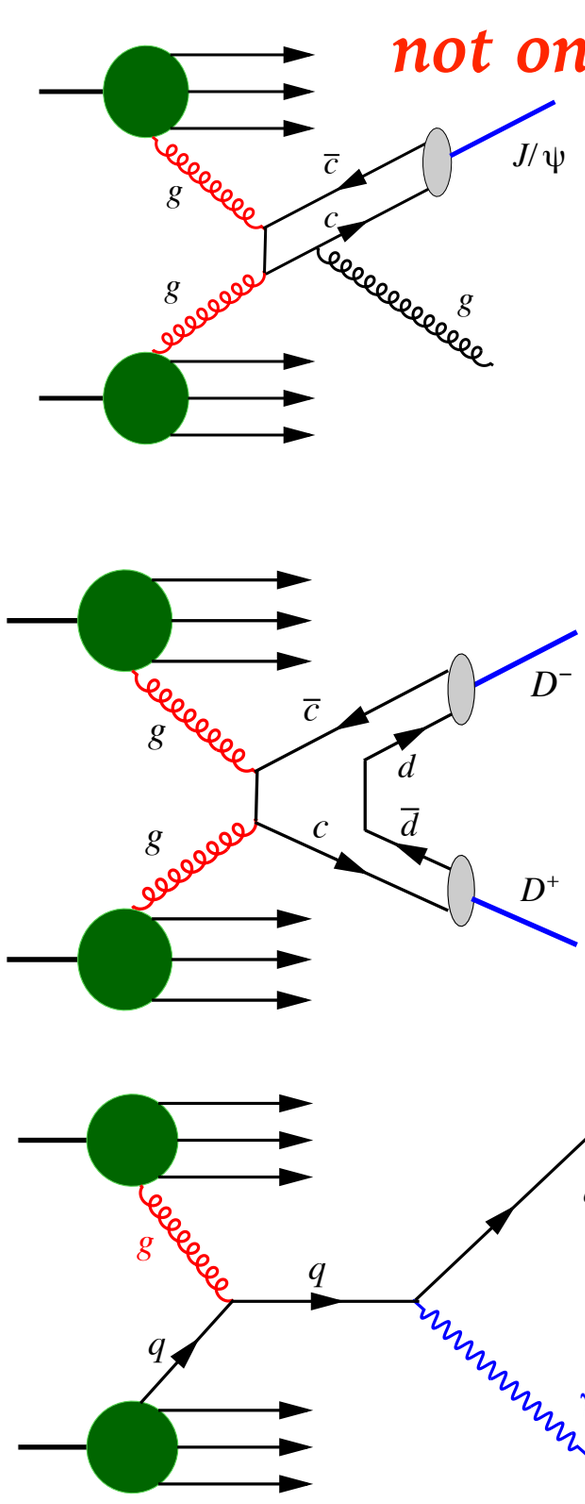
Gluon Boer-Mulders function

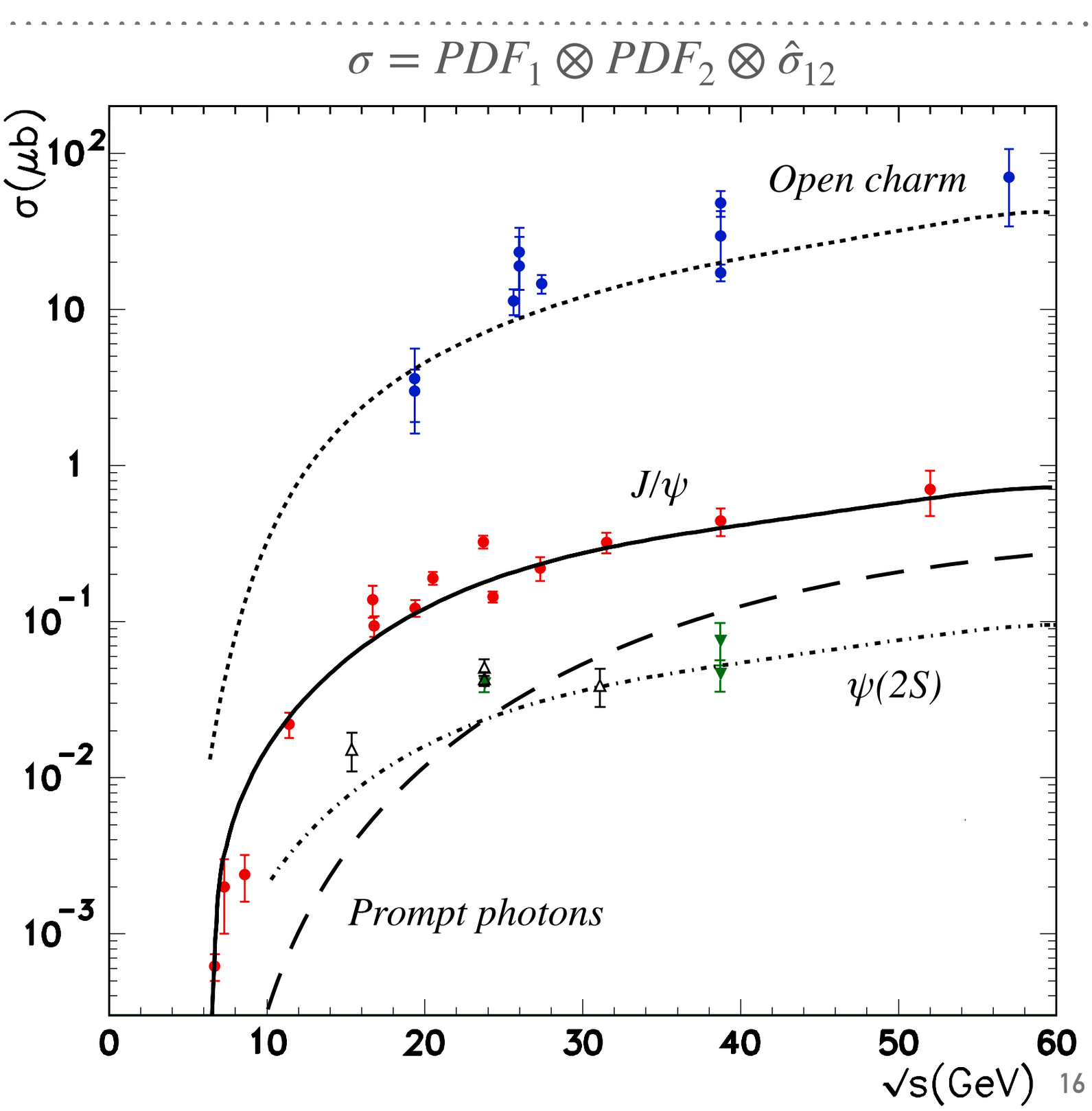
GLUONS	*unpolarized*	*circular*	*linear*
U	f_1^g		$h_1^{\perp g}$
L		g_{1L}^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	$h_{1T}^g, h_{1T}^{\perp g}$

Gluon Sivers function

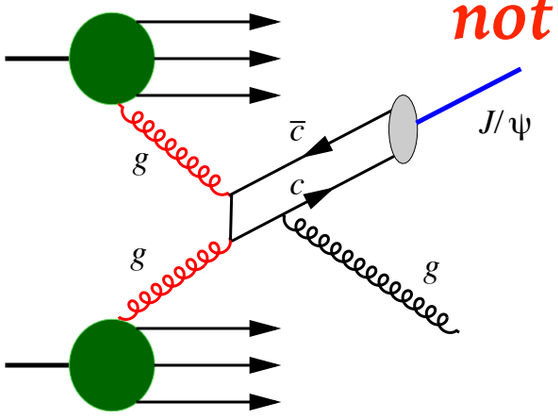
Gluon transversity in deuteron

GLUON PROBES AT SPD





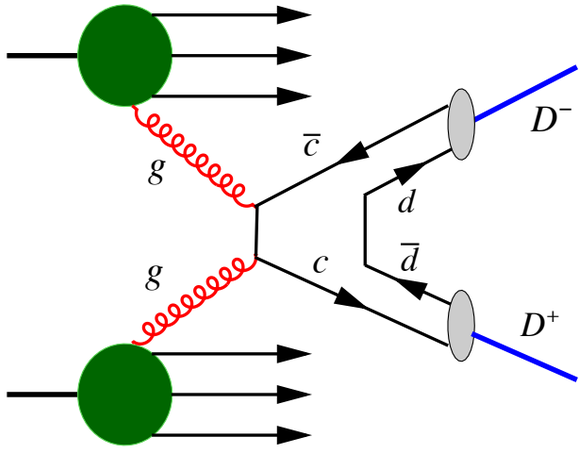
GLUON PROBES AT SPD



not only J/ψ!

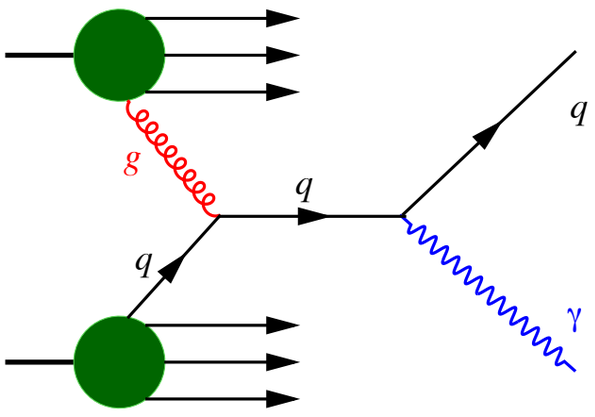
Sharp signal
Relatively large cross section

Model-dependent probability for $c\bar{c} \to [c\bar{c}]$



Largest cross section

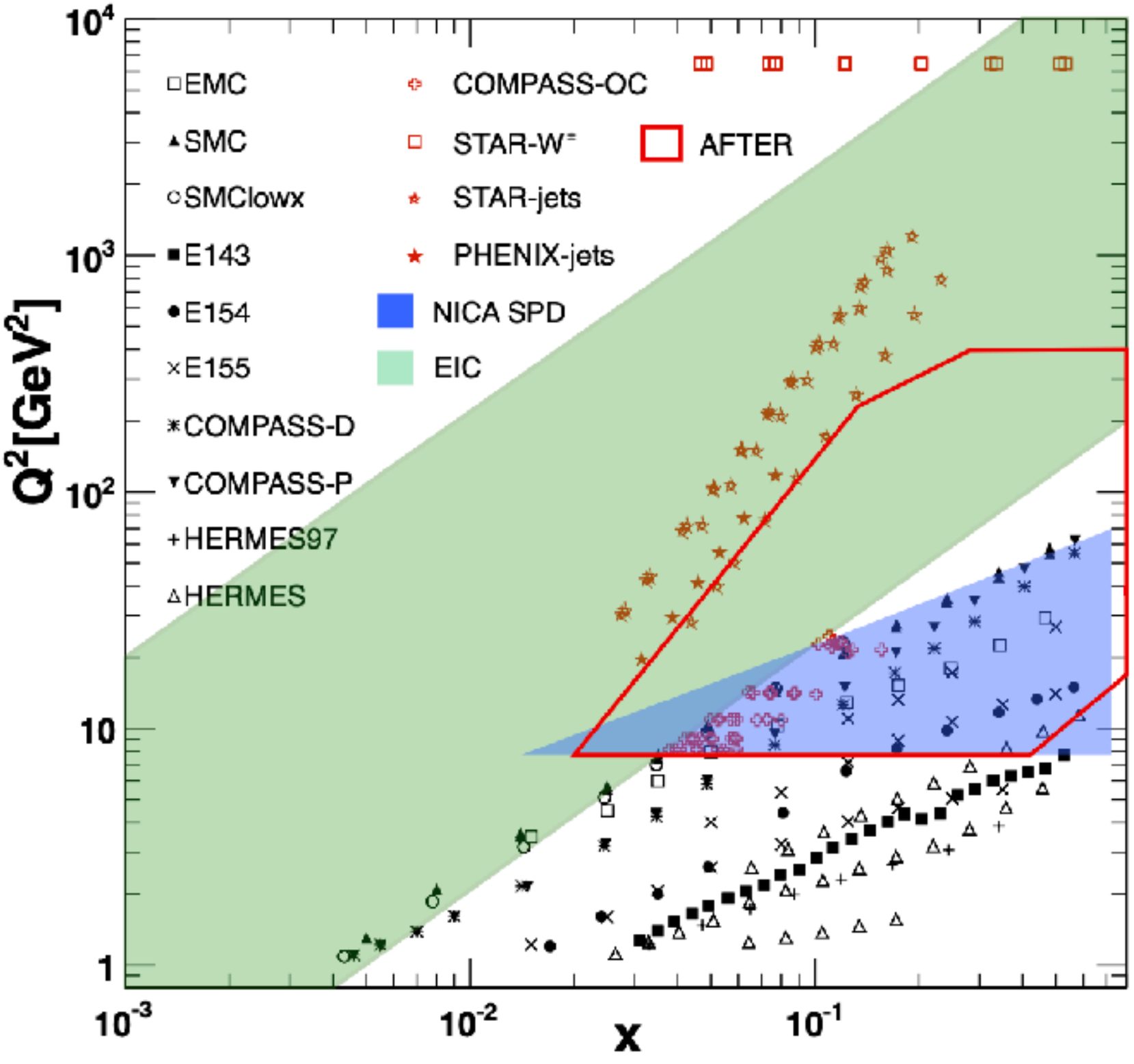
Challenging experimental requirements
Model-dependent fragmentation functions



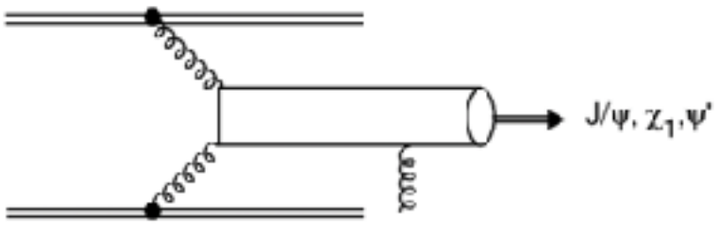
Almost no fragmentation

Strong background especially at low p_T

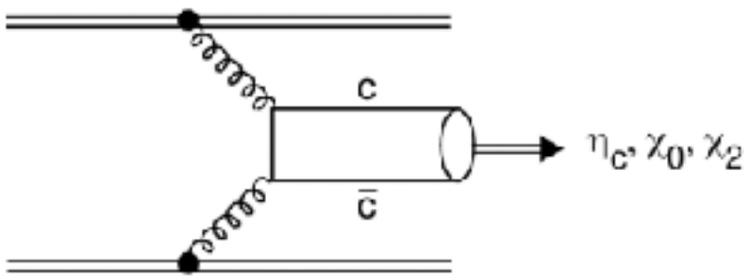
CINEMATIC RANGE

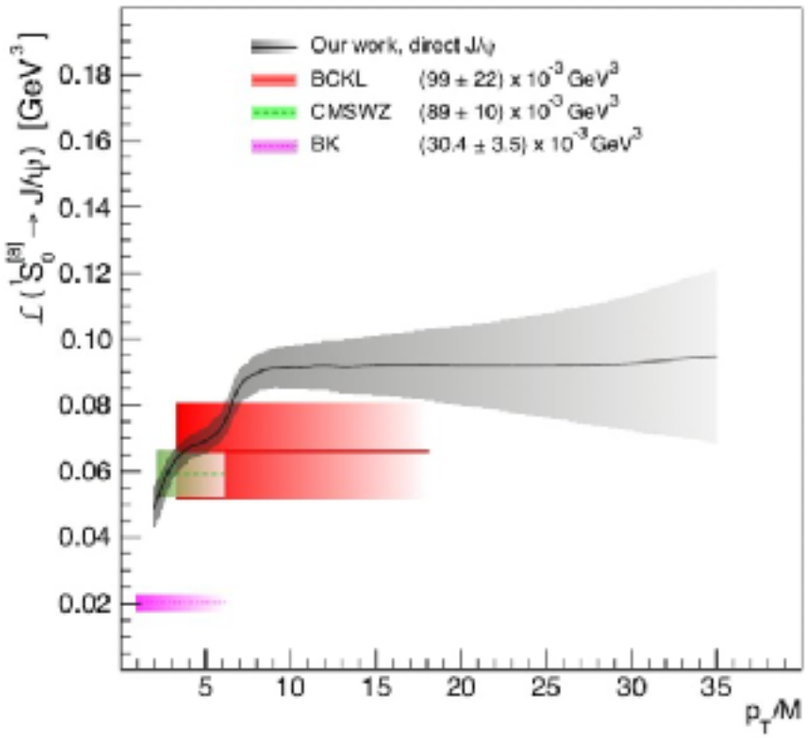


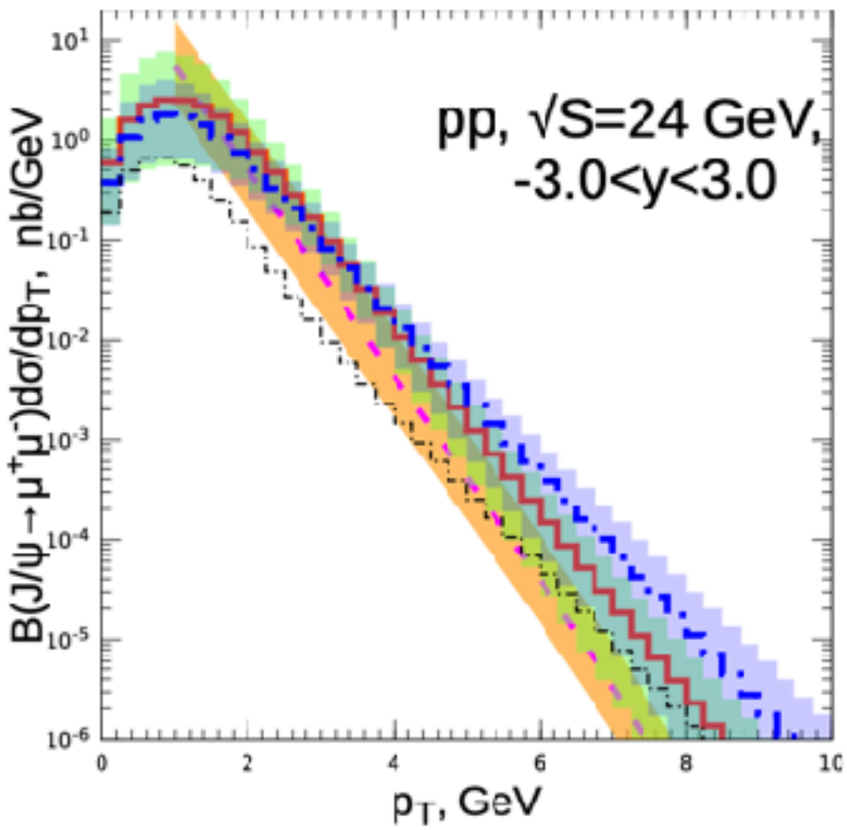
CHARMONIA PRODUCTION

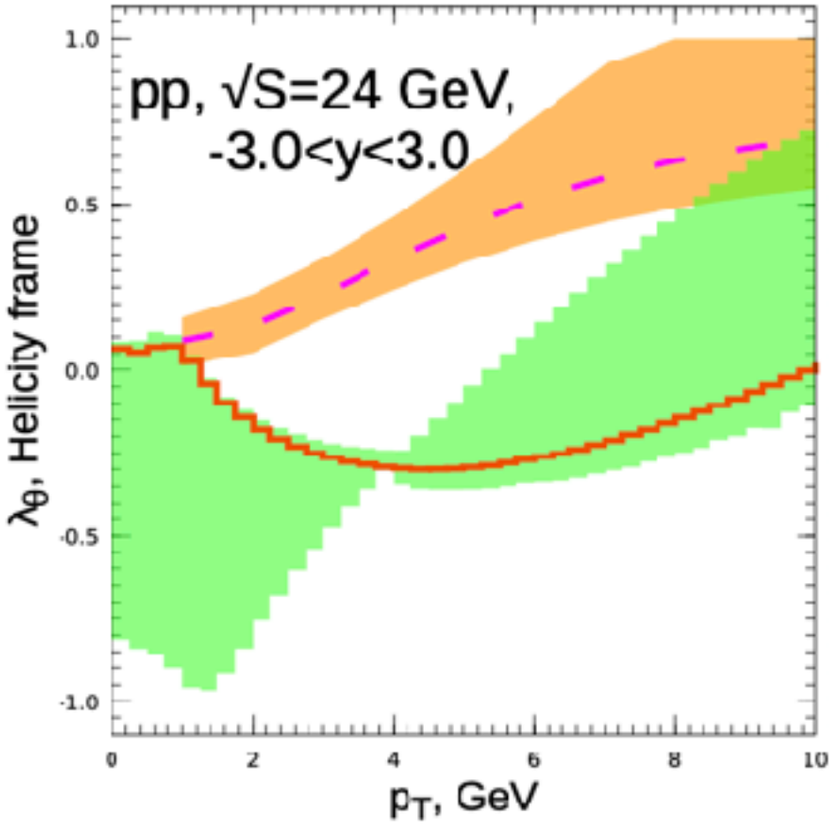


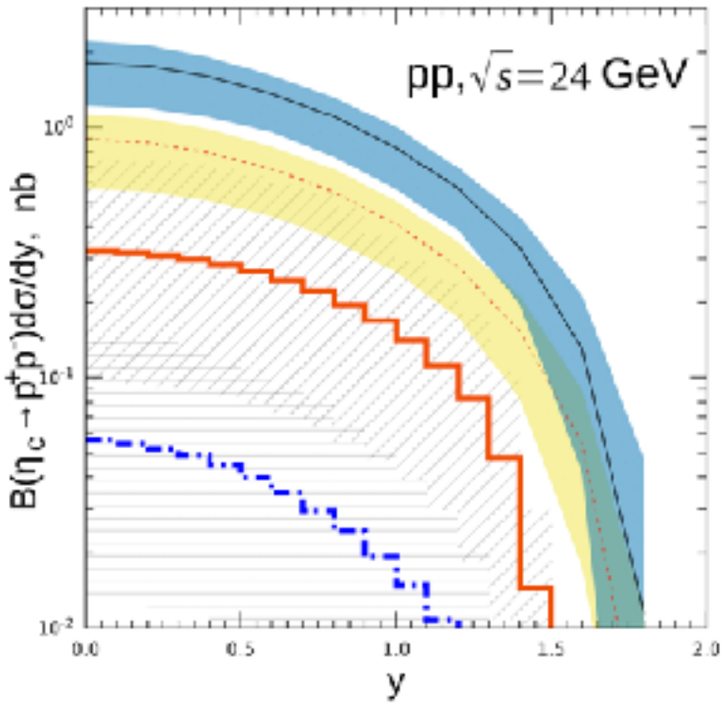
NRQCD — LDMEs



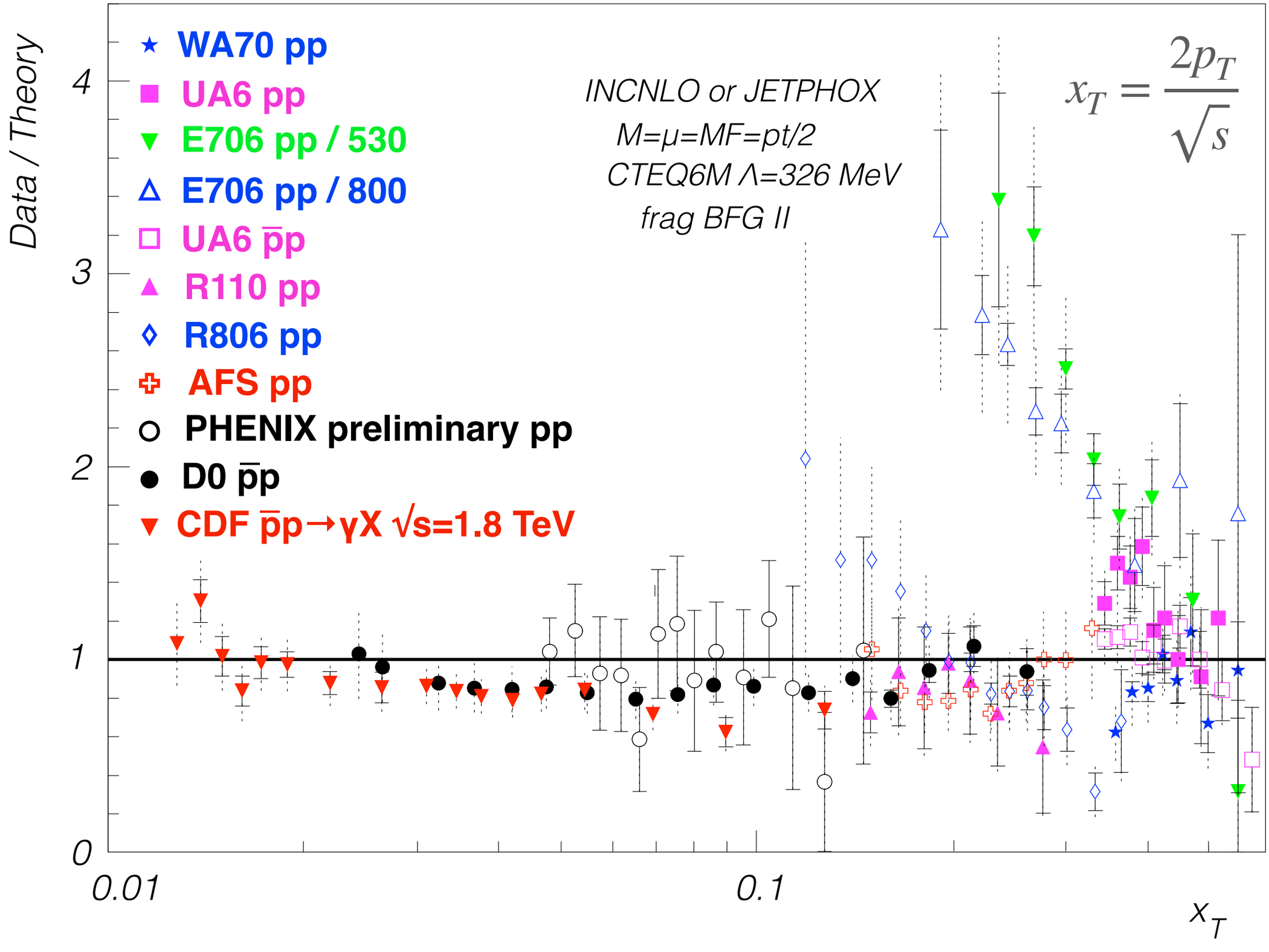




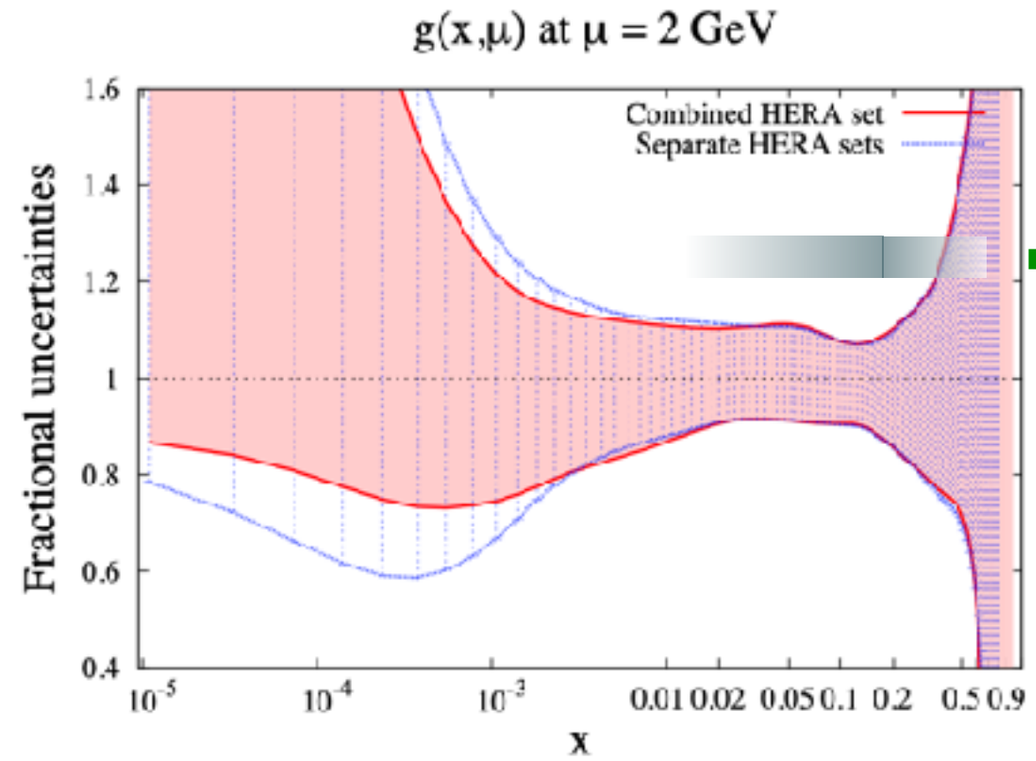




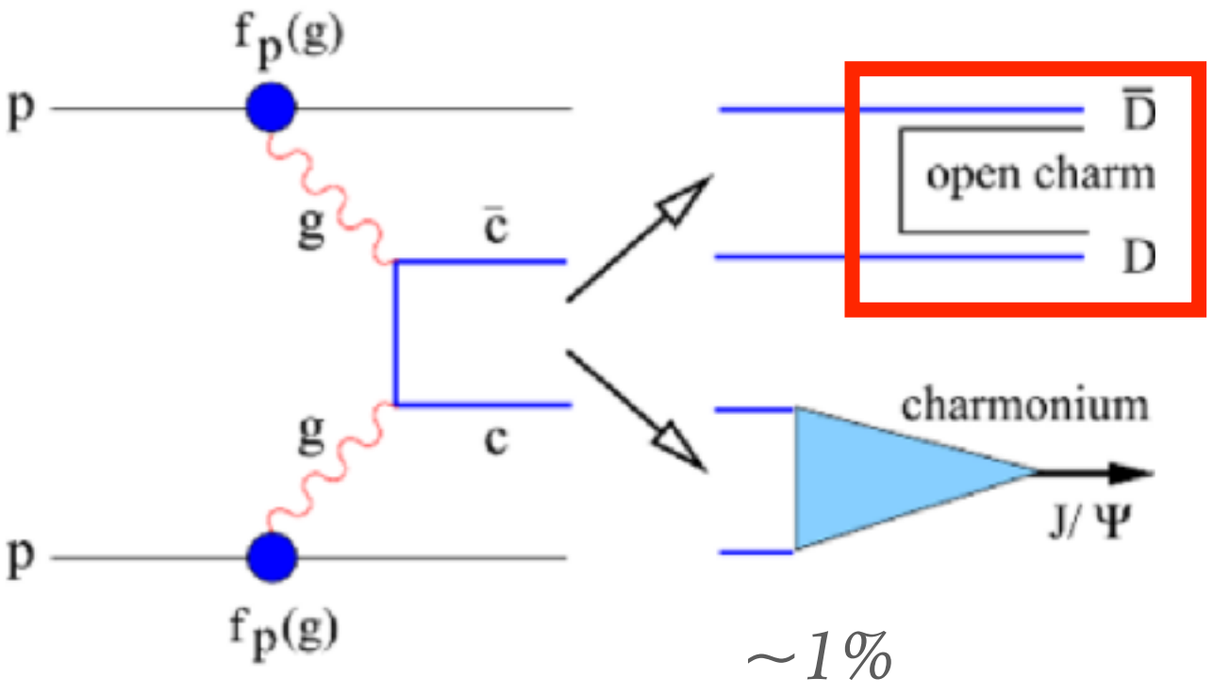
PROMPT PHOTON PUZZLE



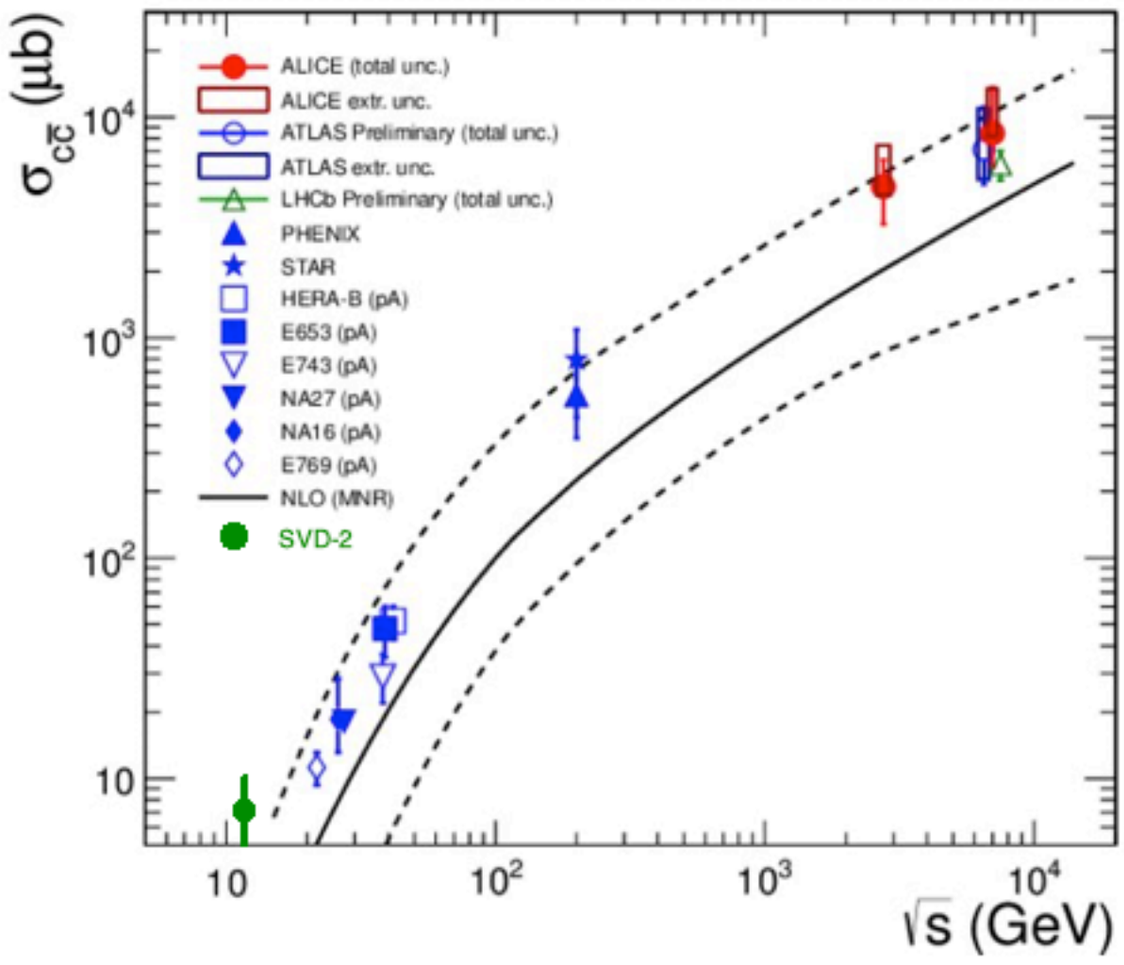
UNPOLARIZED GLUONS IN PROTON AT HIGH x



Good opportunity for SPD

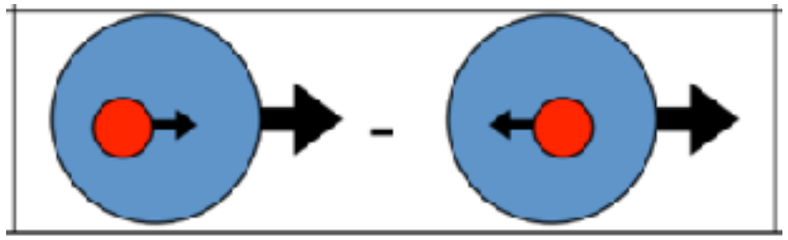


~1%

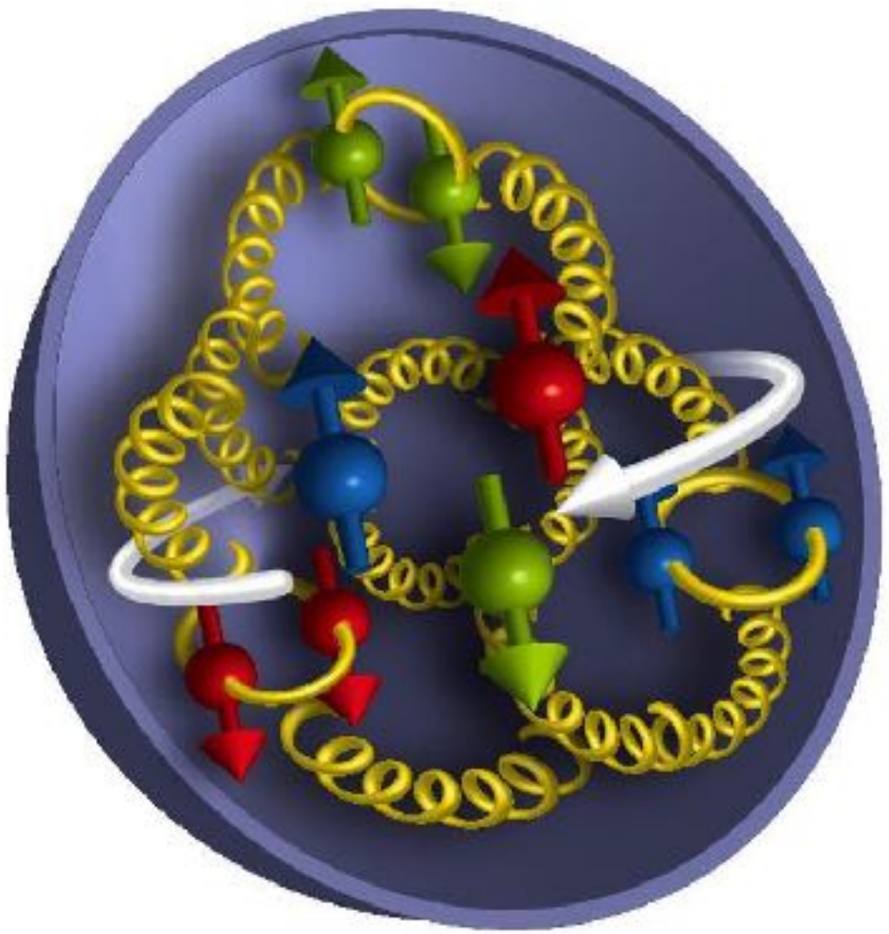


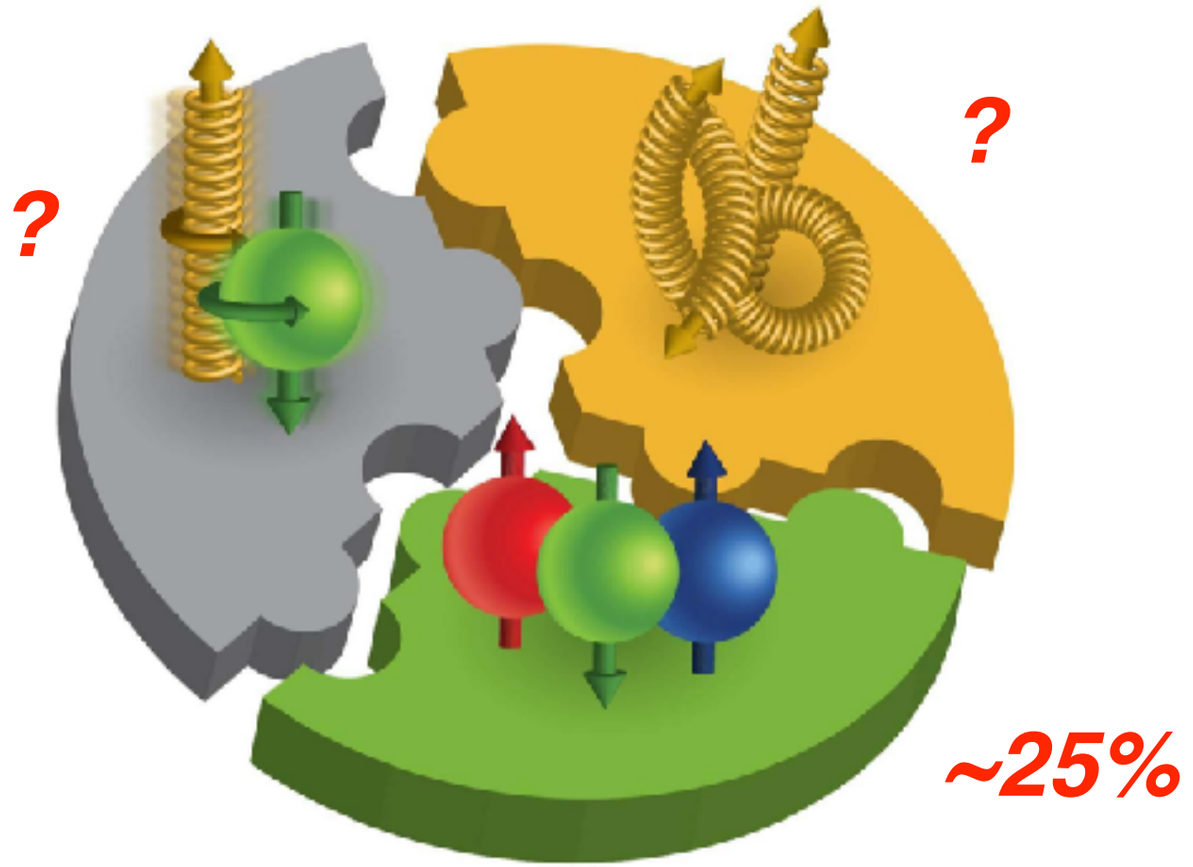
GLUON HELICITY FUNCTION Δg(x) : SPIN CRISIS

Δg(x) :



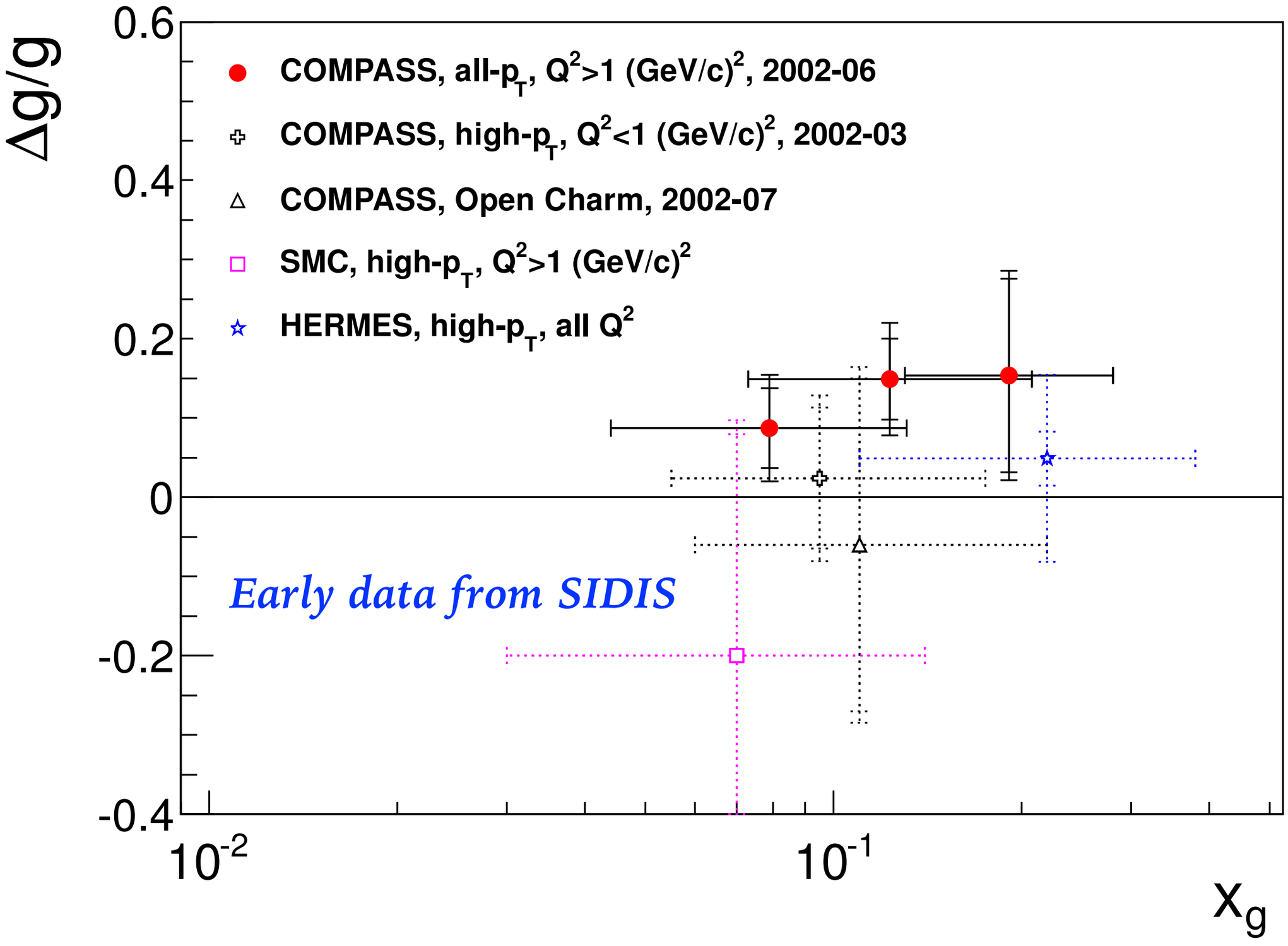
$$\Delta G = \int_0^1 \Delta g(x) dx$$





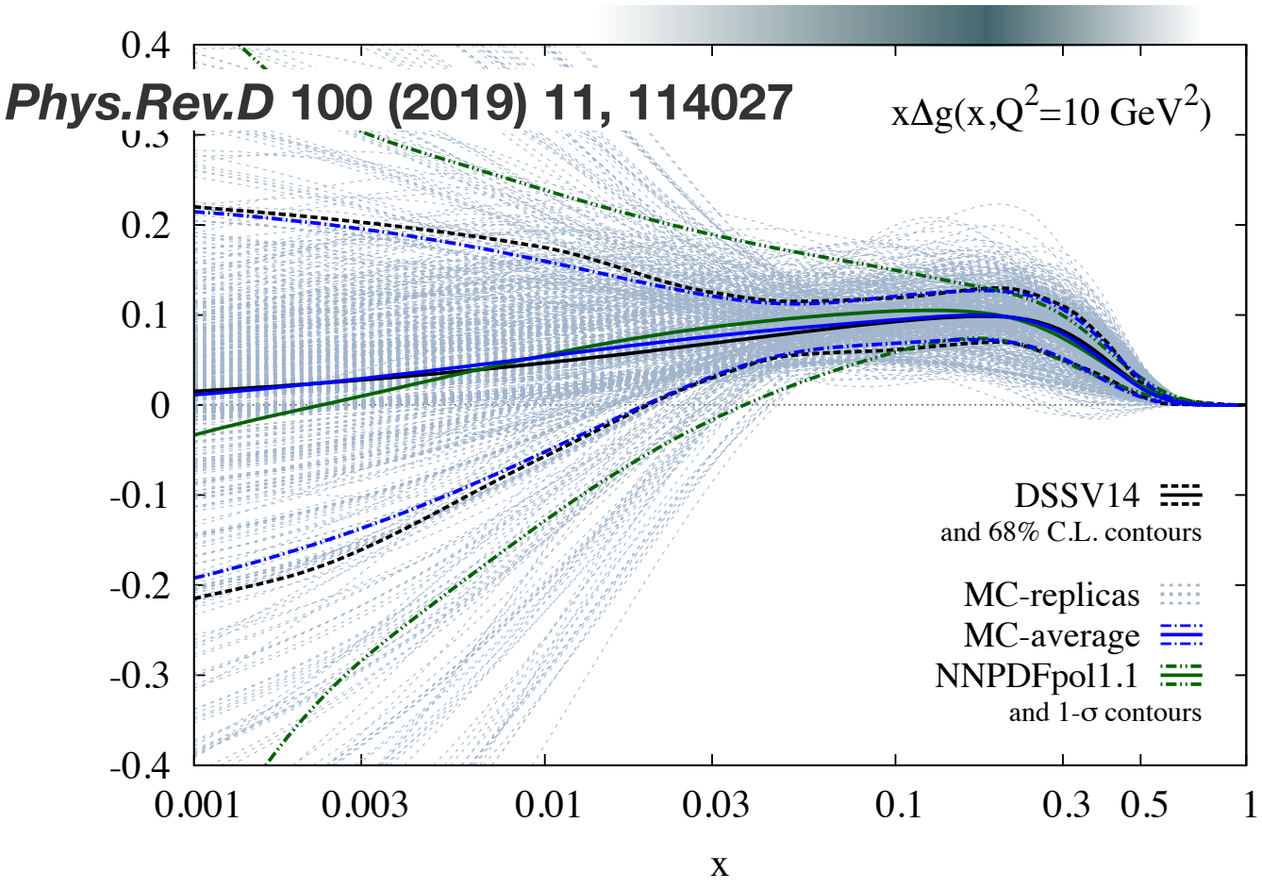
$$S_N = ½ = ½\,\Delta\Sigma + \Delta G + L$$

GLUON HELICITY FUNCTION Δg(x)

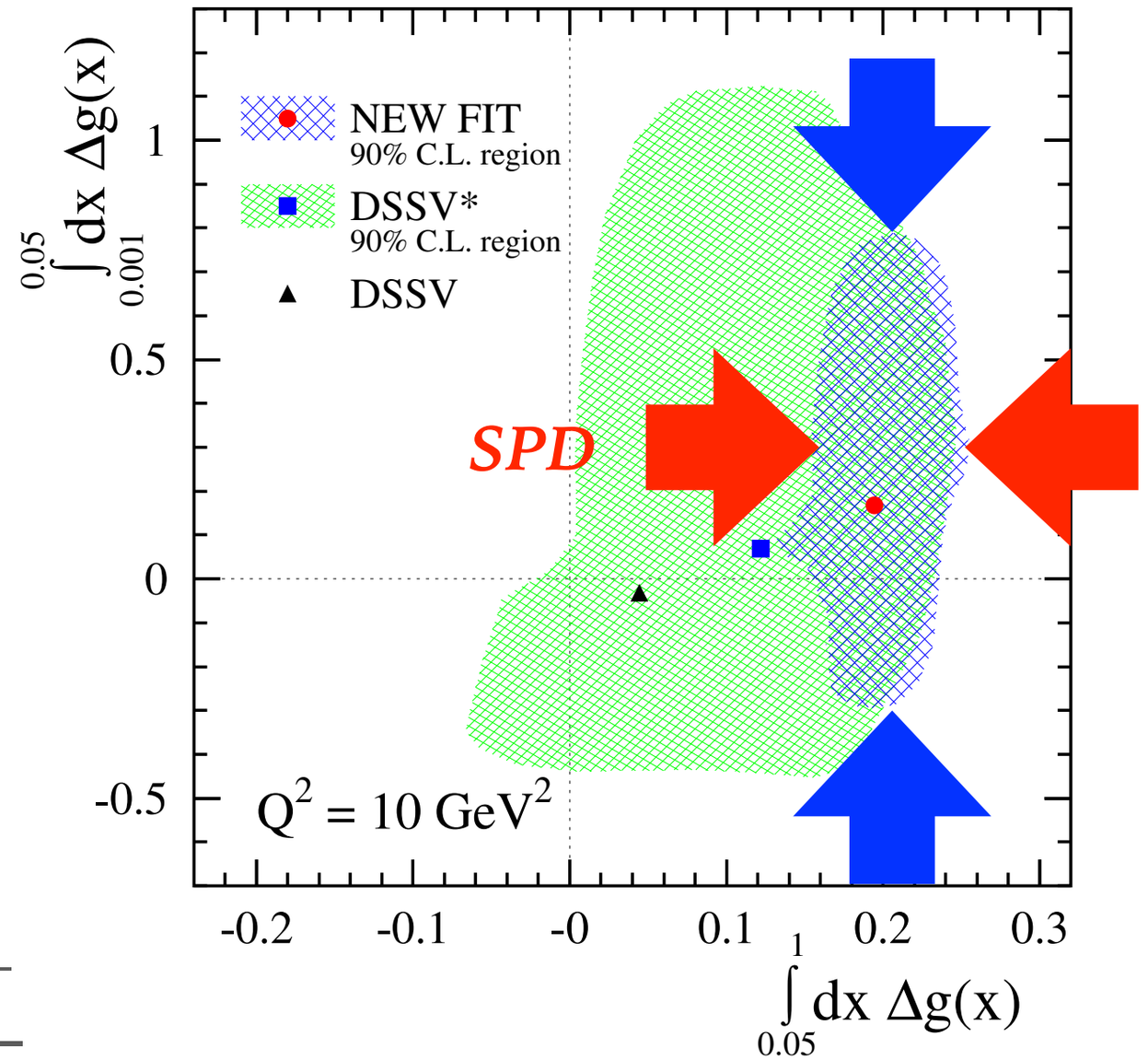


GLUON HELICITY FUNCTION Δg(x)

accessible with SPD



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

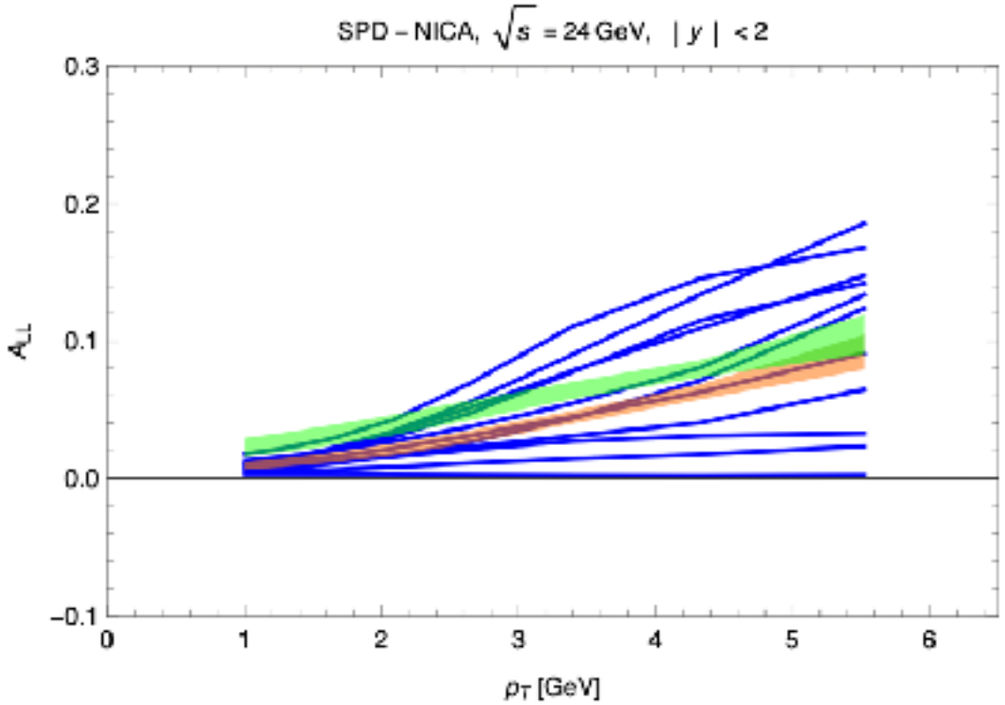


SPD could help to reduce uncertainty of ΔG at large x

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

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

GLUON HELICITY FUNCTION Δg(x) : EXPECTATIONS FOR A_{LL}



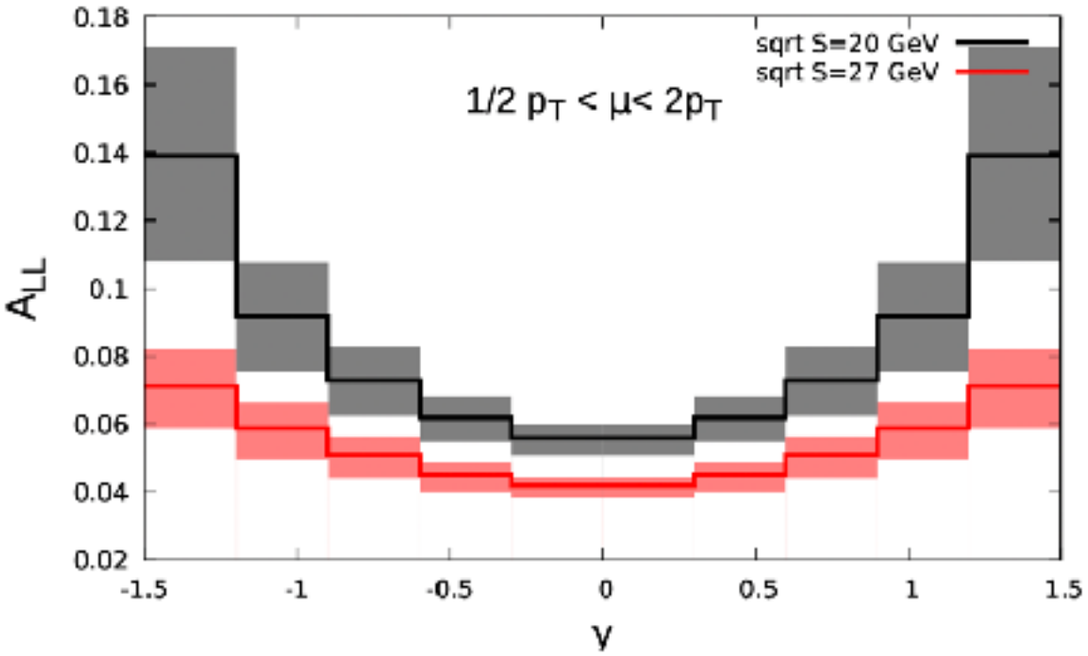
$gg \rightarrow J/\psi g$

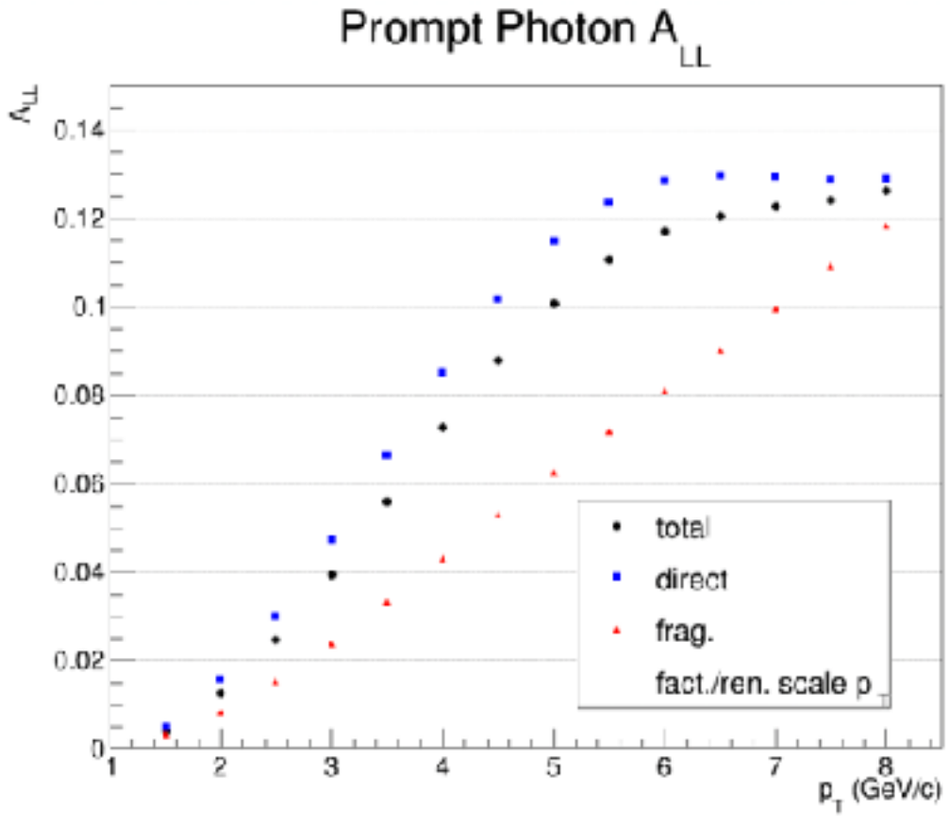
M. Nefedov

W. Vogelsang

A. Shipilova

$qg \rightarrow q\gamma$

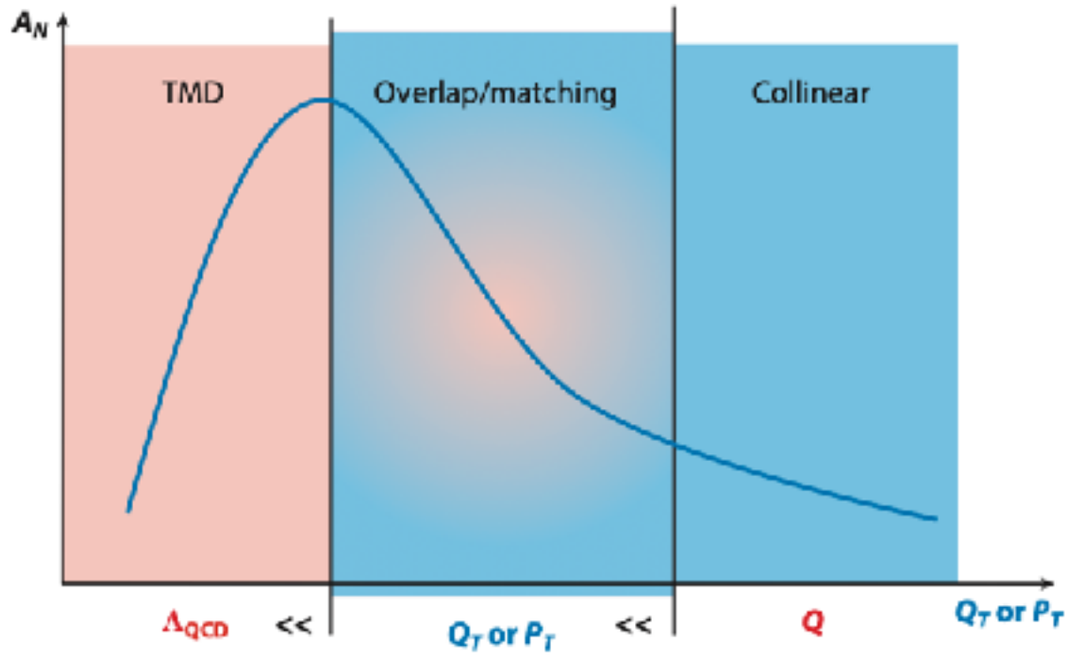




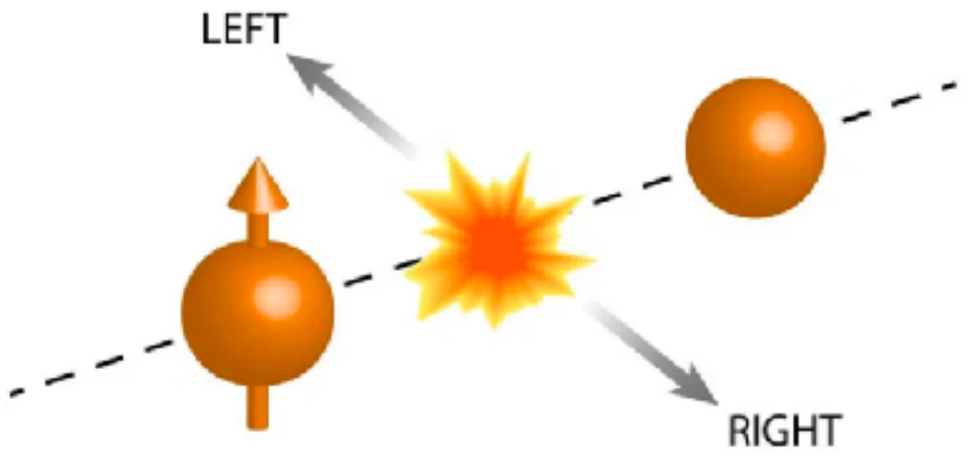
GLUON-INDUCED TMD EFFECTS : GLUON SIVERS FUNCTION $\Delta^g_N(x,k_T)$

1) *Collinear factorization + three-parton correlations in twist-3*
2) *TMD factorization*

Different $<k_T>$ for quarks and gluons?



Sivers effect: *left-right asymmetry of unpolarized k_T distribution in transversely polarized nucleon*



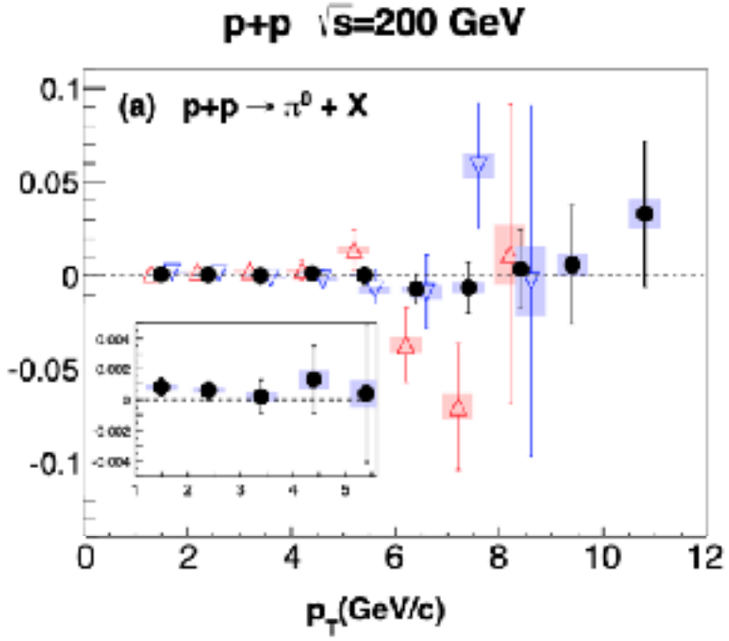
Sivers effect

Collins effect

A_N

- due to fragmentation of polarized quark

GLUON SIVERS FUNCTION $\Delta^{g}_{N}(x,k_T)$

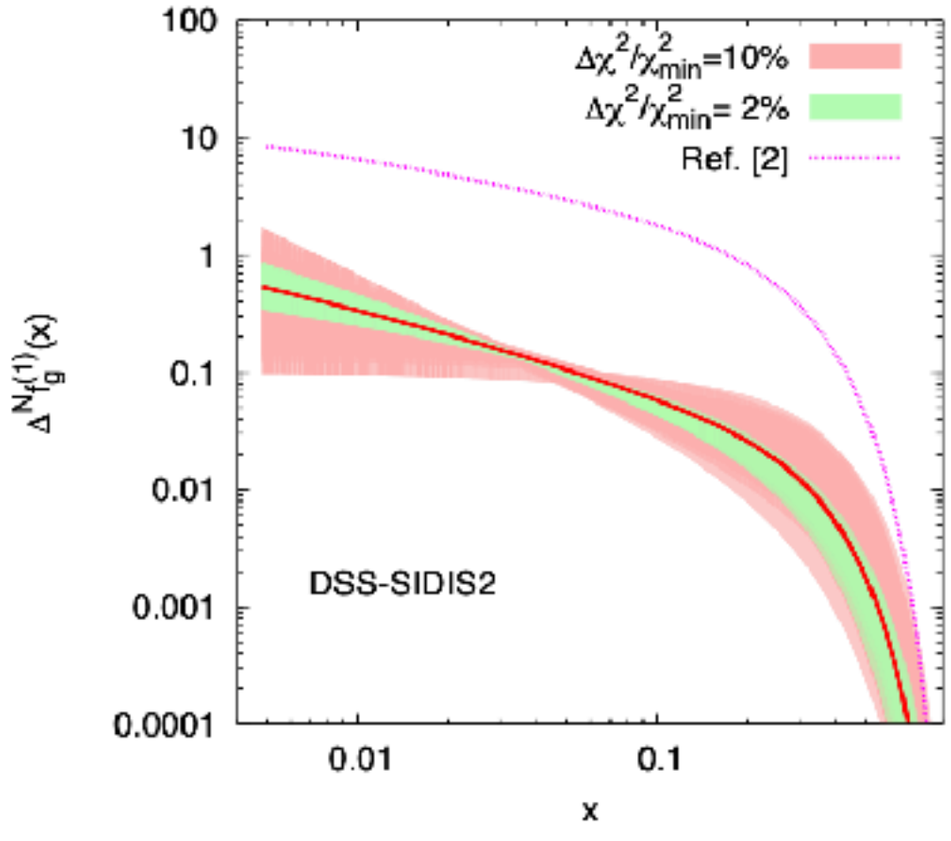


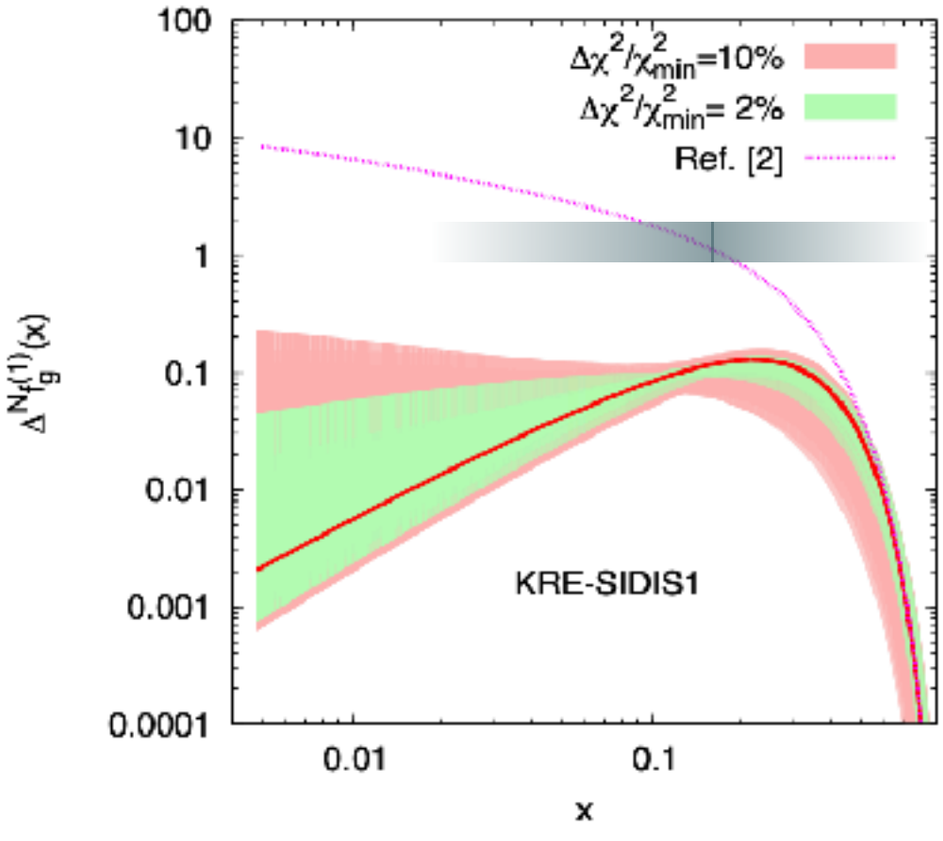
***Phys.Rev.D* 90 (2014) 1, 012006**

PHENIX

First $k_\perp$-moment of the gluon Sivers function

***JHEP* 09 (2015) 119**

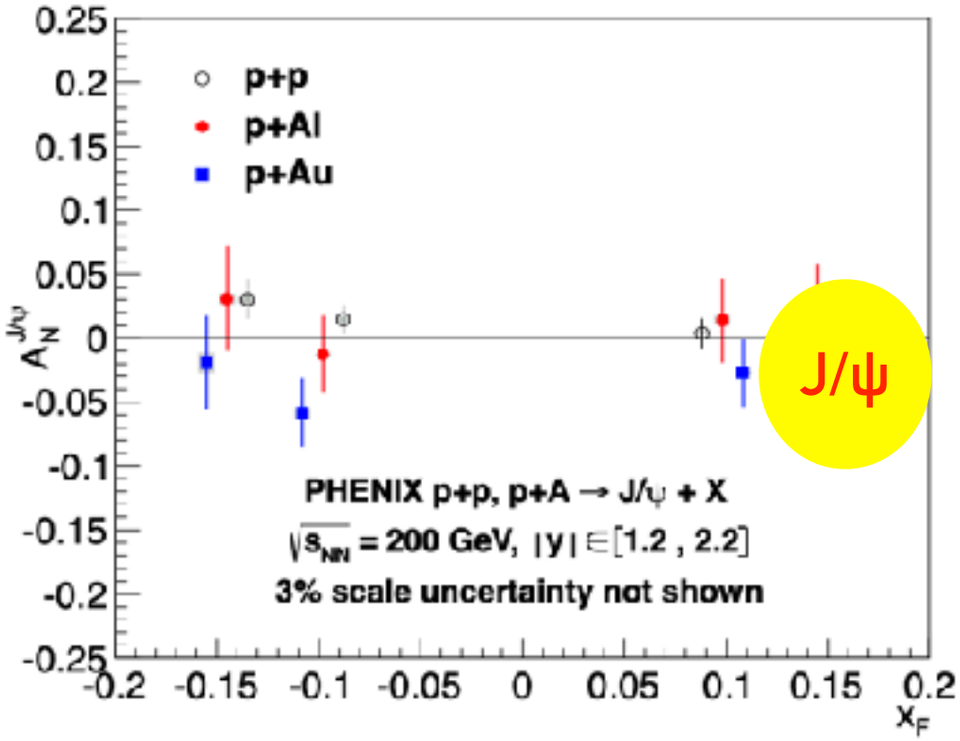


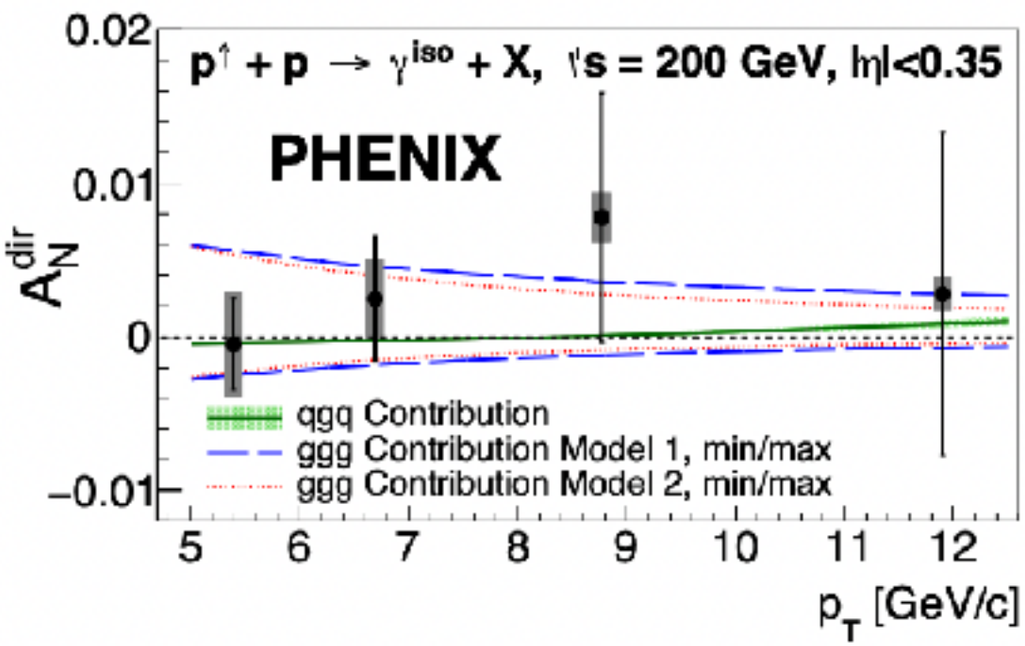


SPD

GLUON-INDUCED TMD EFFECTS : EXISTING RESULTS FOR A_N

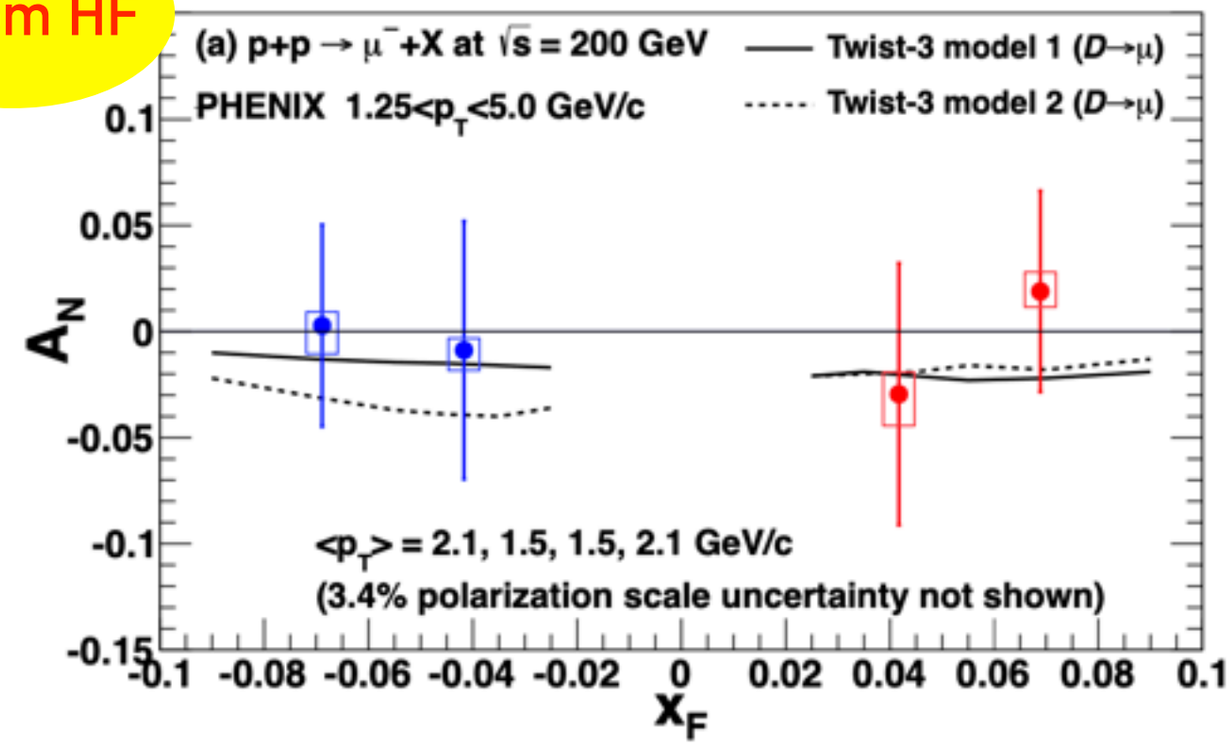
Phys.Rev.D 98 (2018) 1, 012006

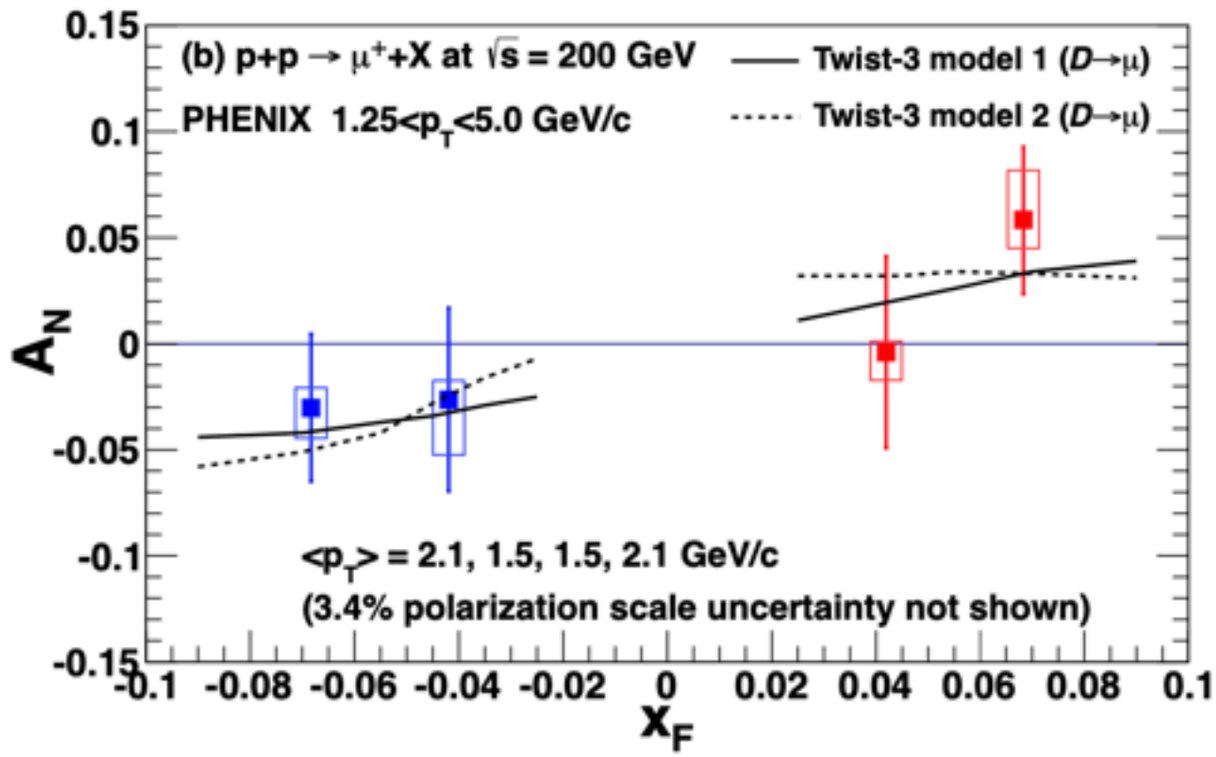




μ from HF

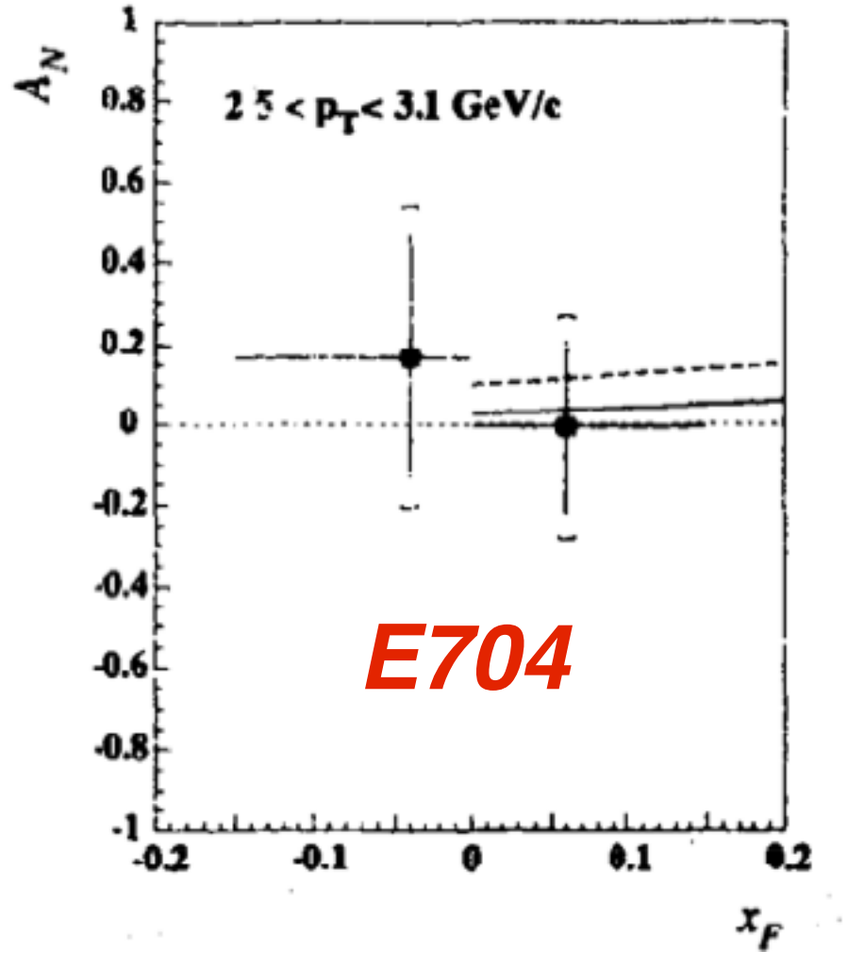
Phys.Rev.D 95 (2017) 11, 112001





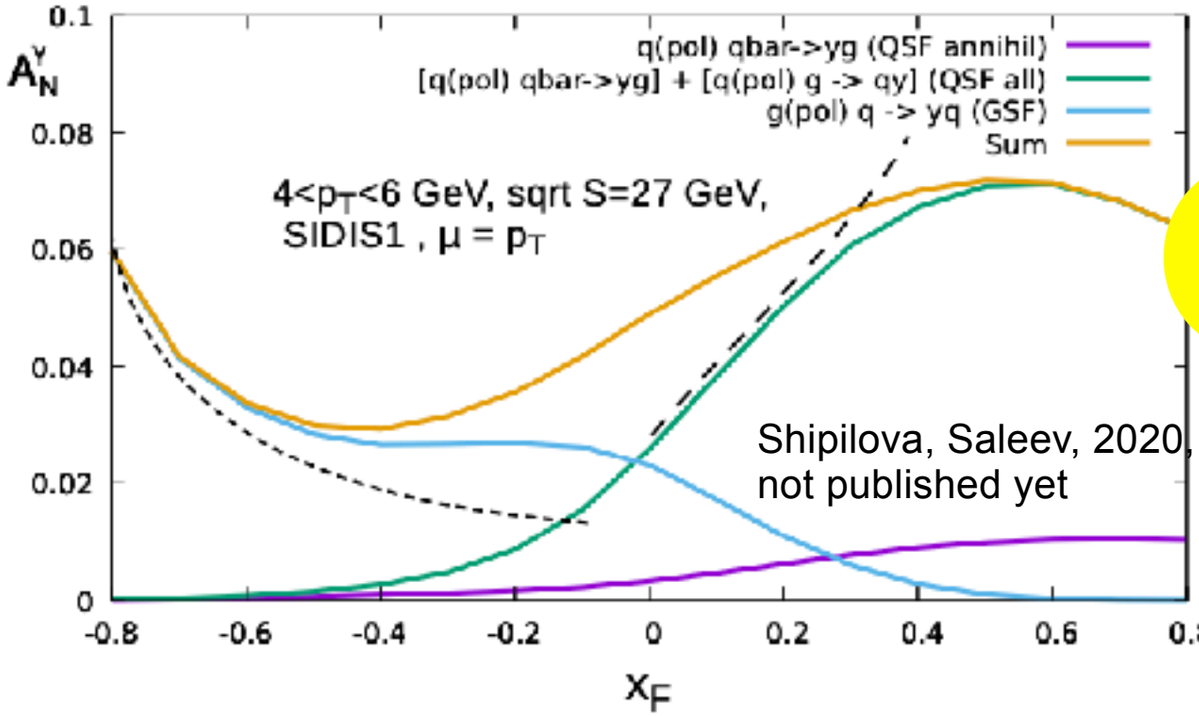
. . . AND AT NICA ENERGIES

Phys. Lett. B 345 (1995)

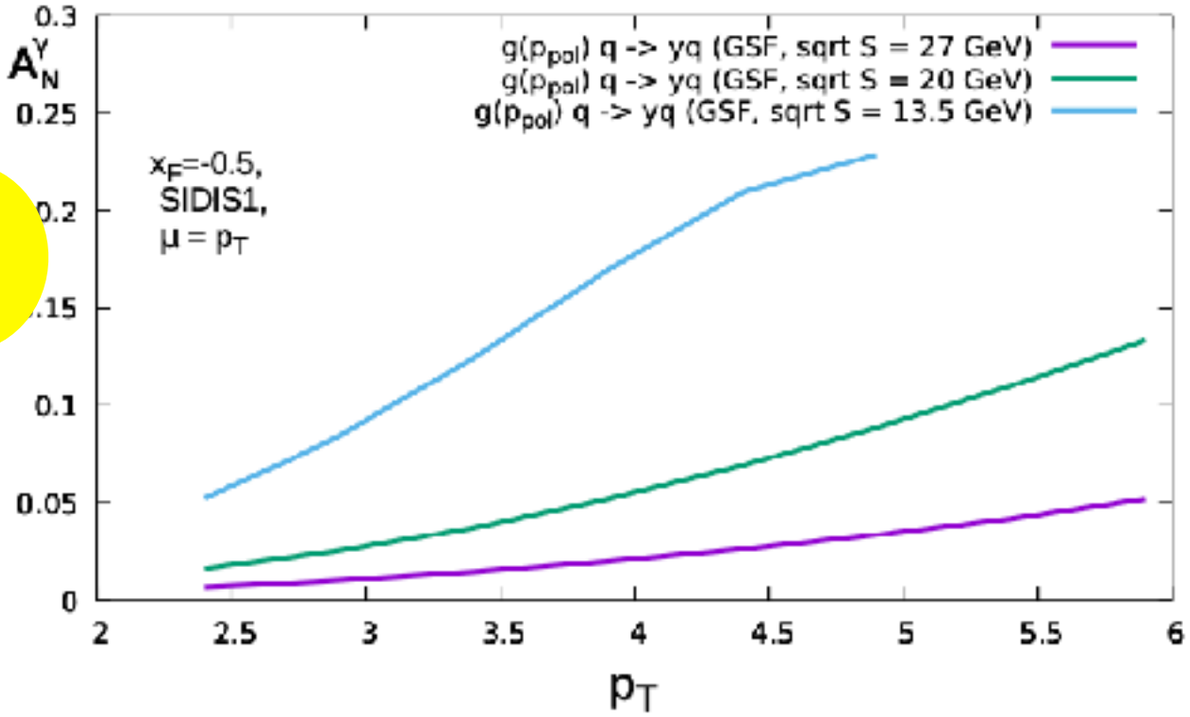


GLUON-INDUCED TMD EFFECTS: EXPECTATIONS FOR A_N

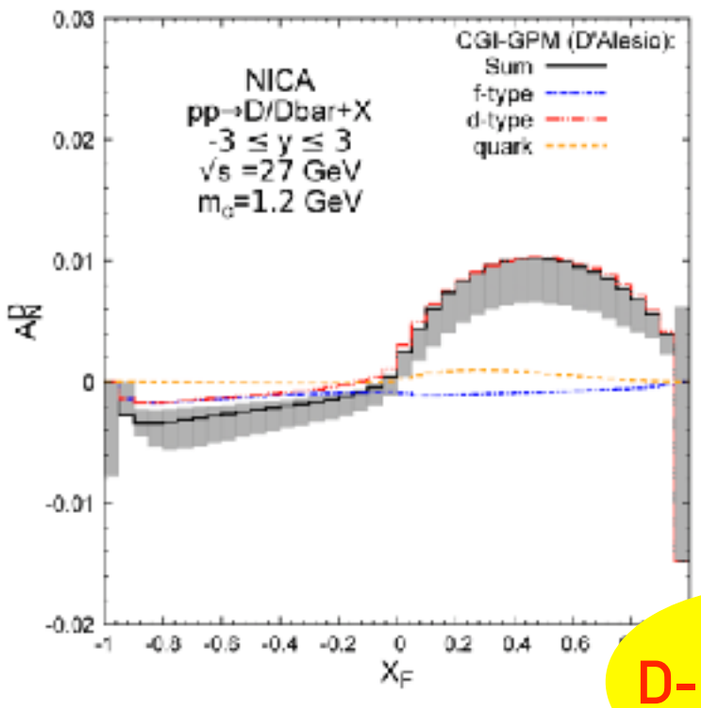
Sivers effect contribution

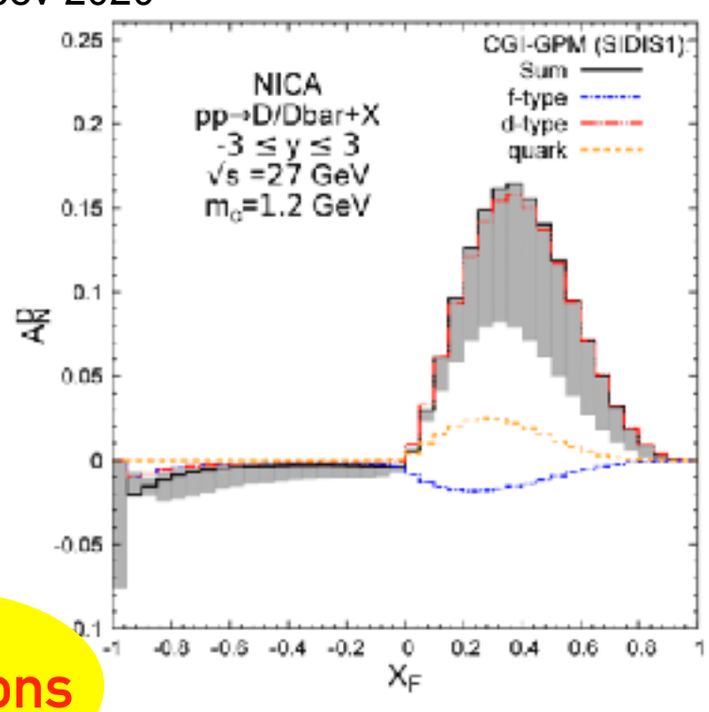


Y

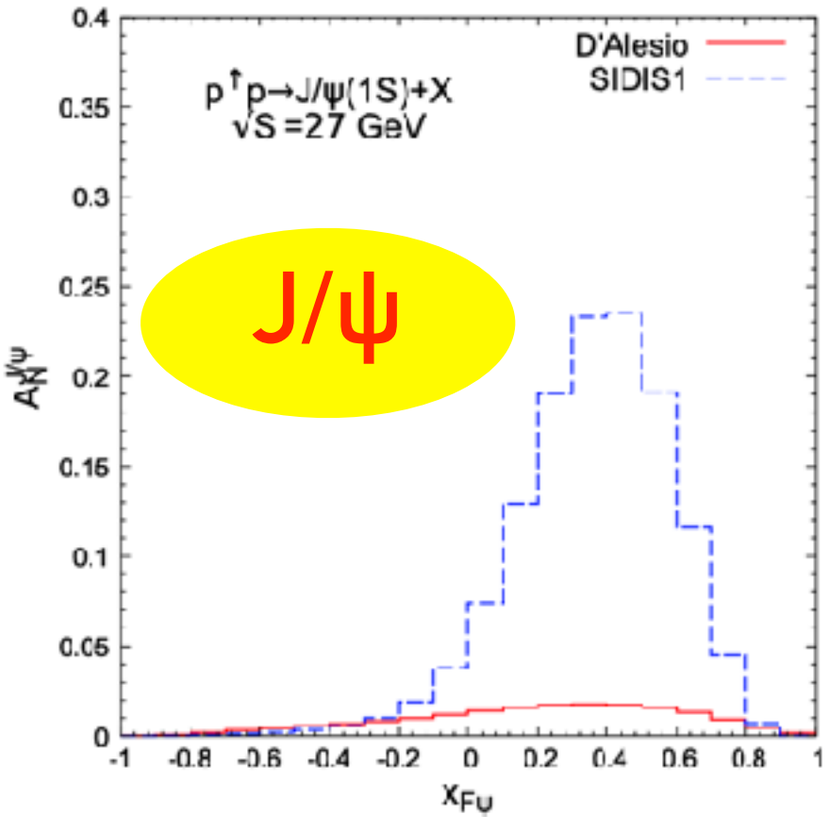


Saleev 2020





D-mesons



GLUON-INDUCED TMD EFFECTS : BOER-MULDERS FUNCTION $h_1^{\perp g}(x,k_T)$

$gg \to D\bar{D}, \gamma\gamma, J/\psi\gamma, \ldots$

The hadronic cross section can be written with corrections of order $\mathcal{O}(\infty/\mathcal{S})$ in the form [D. Boer, P. Mulders, C. Pisano, 2008]

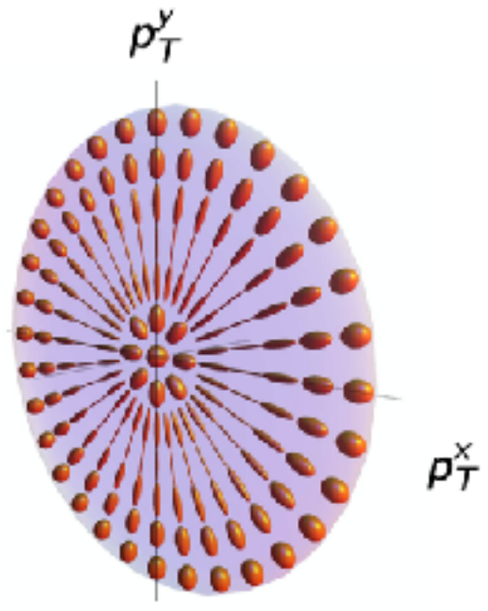
$$\frac{d\sigma(pp\to D\bar{D}X)}{d\eta_1 d\eta_2 d^2k_{1T} d^2k_{2T}} = \frac{\alpha_S}{SK_T^2}\left[A(Q_T^2) + B(Q_T^2)Q_T^2\cos 2(\phi_T - \phi_\perp) + C(Q_T^2)Q_T^4\cos 4(\phi_Q - \phi_K)\right]$$

$$\vec{Q}_T = \vec{k}_{1T} + \vec{k}_{2T}, \qquad \vec{K}_T = (\vec{k}_{1T} - \vec{k}_{2T})/2$$

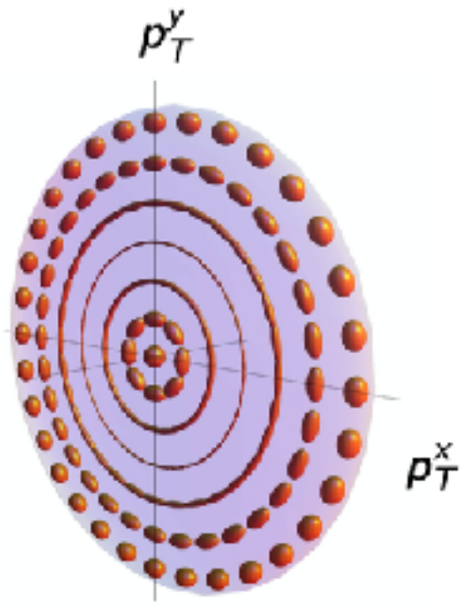
$$A: \quad f_1^q \otimes f_1^{\bar{q}},\ f_1^g \otimes f_1^g\,,$$

$$B: \quad h_1^{\perp q} \otimes h_1^{\perp \bar{q}},\ \frac{M_Q^2}{M_\perp^2} f_1^g \otimes h_1^{\perp g}\,,$$

$$C: \quad h_1^{\perp g} \otimes h_1^{\perp g}\,.$$



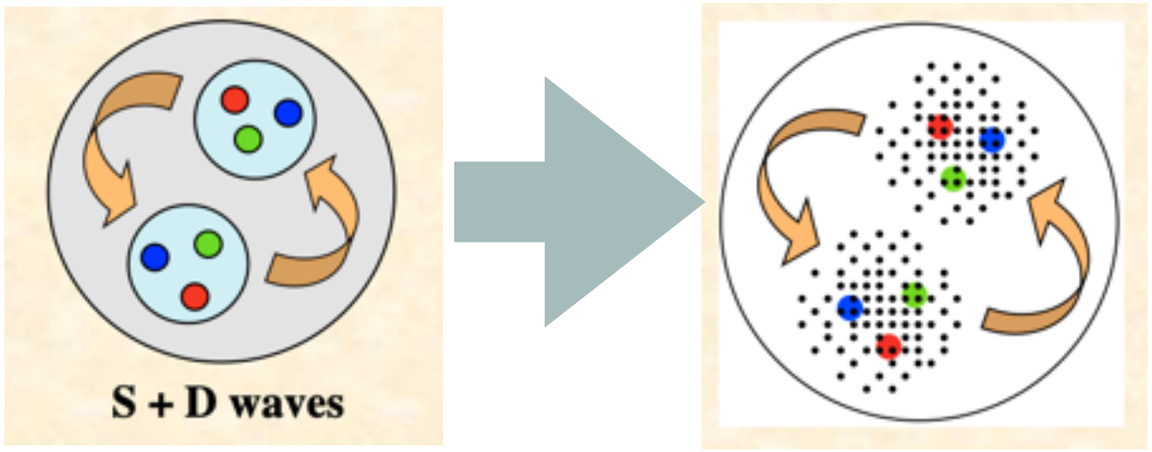
$h_1^{\perp g} > 0$



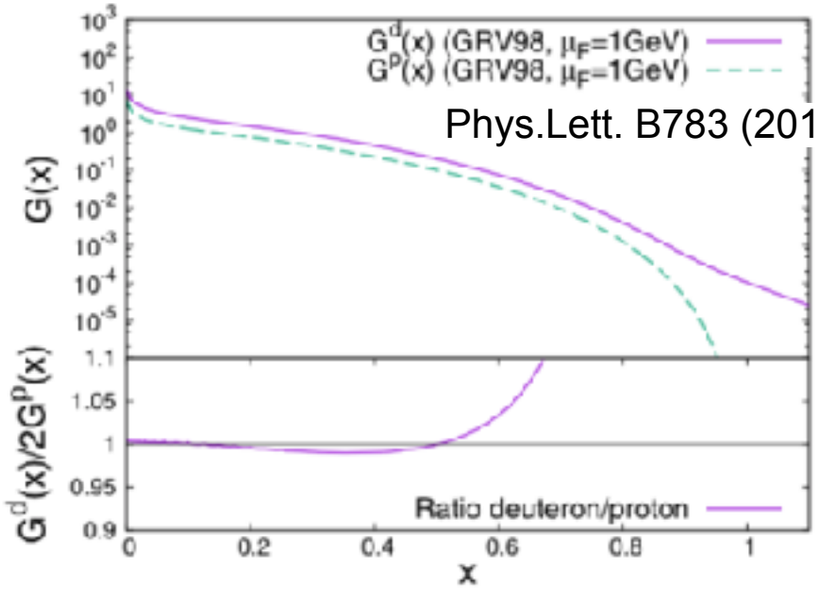
$h_1^{\perp g} < 0$

UNPOLARIZED GLUONS IN DEUTERON AT HIGH x

S. Kumano



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

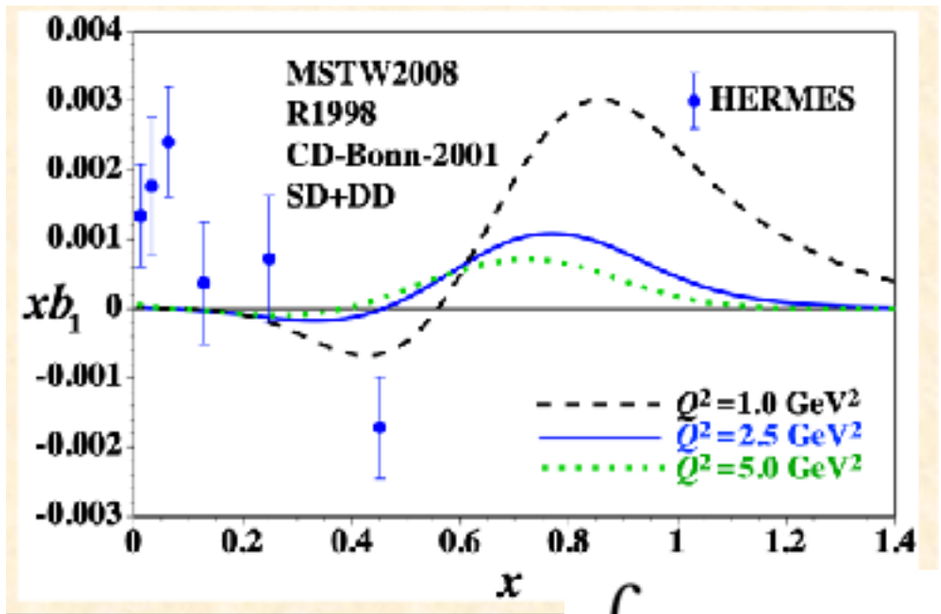


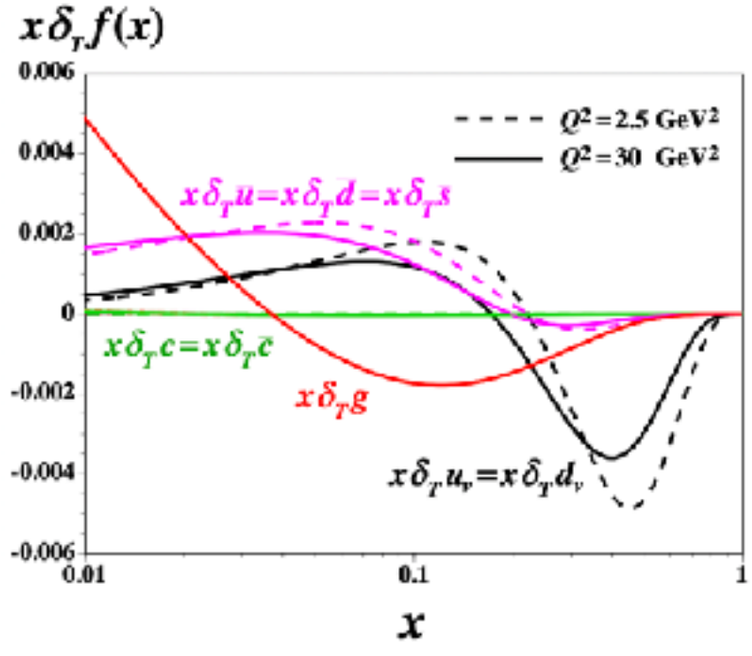
Phys.Lett. B783 (2018) 287-293

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

hidden color up to 90% at some models!

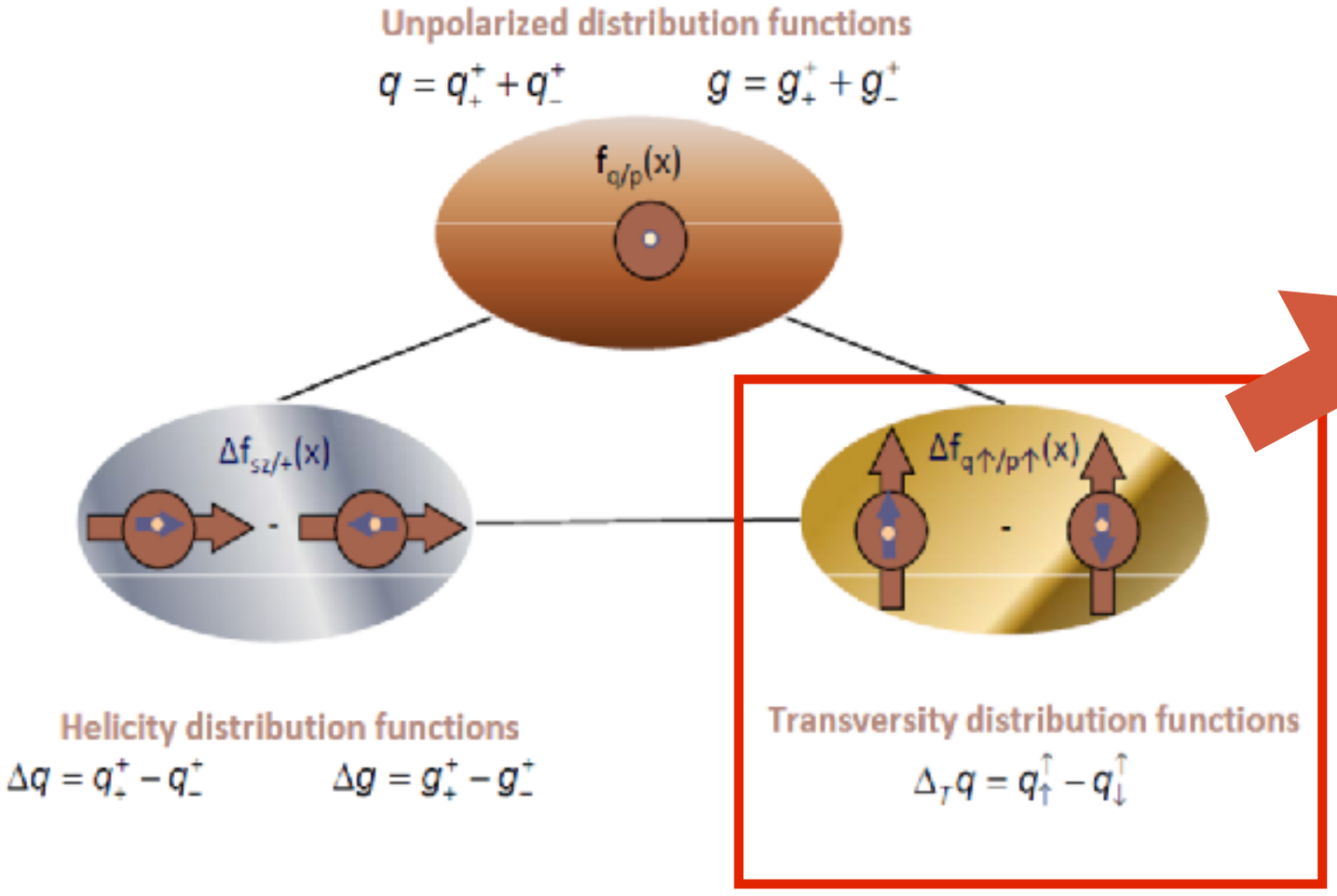
G. A. Miller, Phys.Rev. C89 (2014) no.4, 045203





$$\int dx\, b_1(x)_{\mathrm{LO}} = -\frac{5}{24}\lim_{t\to 0} t\, F_Q(t) + \sum_i e_i^2 \int dx\, \delta_T \bar{q}_i(x),$$

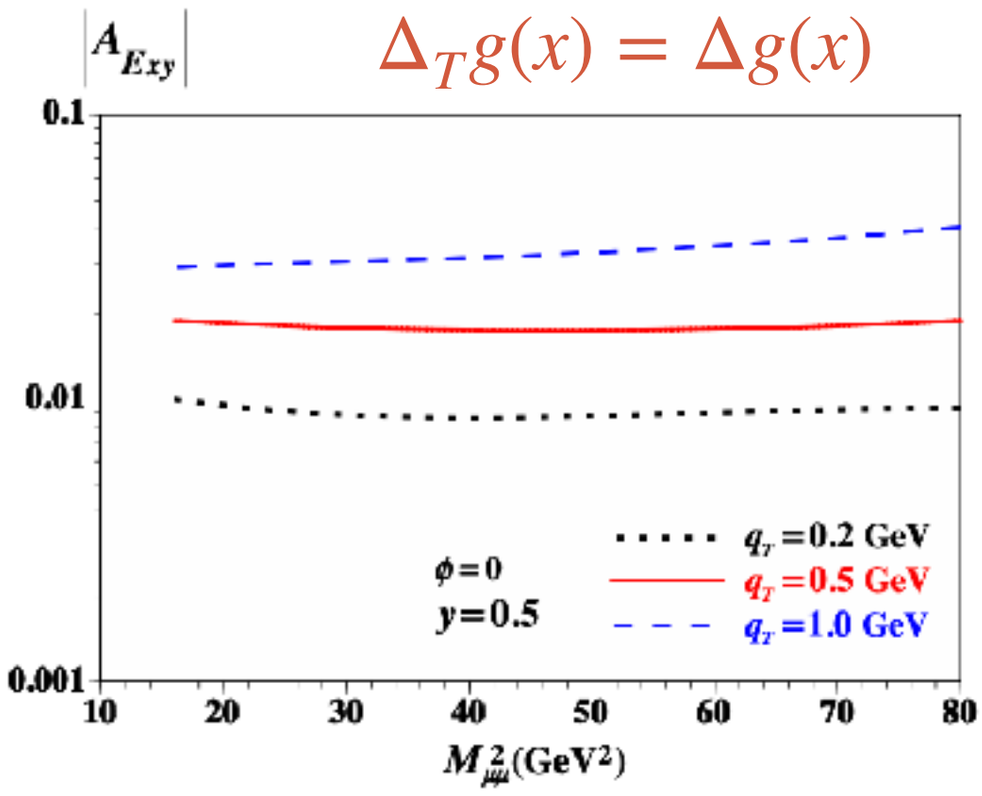
GLUON TRANSVERSITY $\Delta g_T(x)$ IN DEUTERON



Transversity function** is related to spin-flip amplitude but $\Delta s=2$ is **impossible in LO for spin-1/2 hadron.

*But it **nonzero gluon transversity** is possible already **in LO in deuteron** due to non-nucleonic gluon component! It could be accessed via double transverse spin asymmetry!*

Sh. Kumano for DY:
$\Delta_T g(x) = \Delta g(x)$

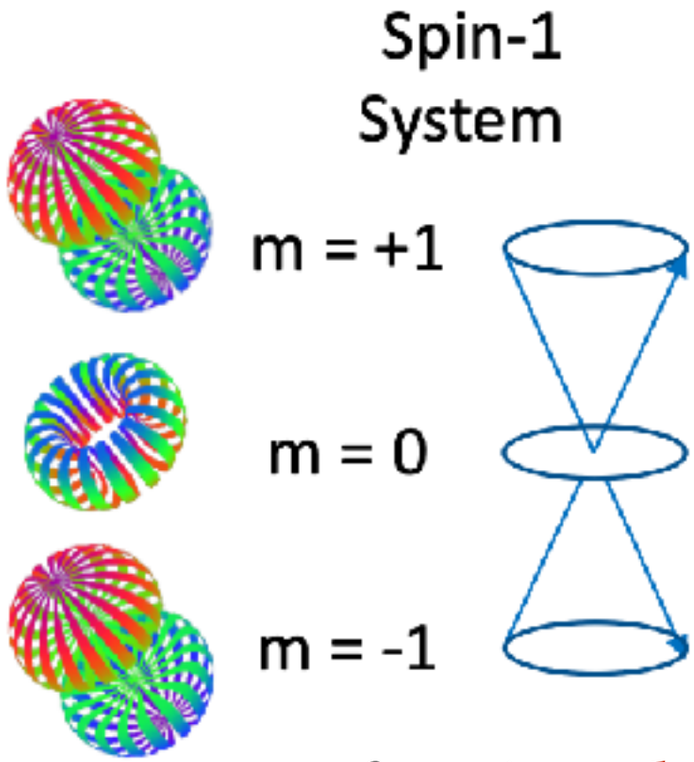


RATES FOR MAIN PROBES

Probe	$\sigma_{27\,\mathrm{GeV}}$, nb (×BF)	$\sigma_{13.5\,\mathrm{GeV}}$, nb (×BF)	$N_{27\,\mathrm{GeV}}$, 10^6	$N_{13.5\,\mathrm{GeV}}$ 10^6
Prompt-γ ($p_T > 3$ GeV/c)	35	2	35	0.2
J/ψ	200	60		
$\to \mu^+\mu^-$	12	3.6	12	0.36
$\psi(2S)$	25	5		
$\to J/\psi\pi^+\pi^- \to \mu^+\mu^-\pi^+\pi^-$	0.5	0.1	0.5	0.01
$\to \mu^+\mu^-$	0.2	0.04	0.2	0.004
$\chi_{c1} + \chi_{c2}$	200			
$\to \gamma J/\psi \to \gamma\mu^+\mu^-$	2.4		2.4	
η_c	400			
$\to p\bar{p}$	0.6		0.6	
Open charm: $D\overline{D}$ pairs	14000	1300		
Single D-mesons				
$D^+ \to K^-2\pi^+$ ($D^- \to K^+2\pi^-$)	520	48	520	4.8
$D^0 \to K^-\pi^+$ ($\overline{D}^0 \to K^+\pi^-$)	360	33	360	3.3

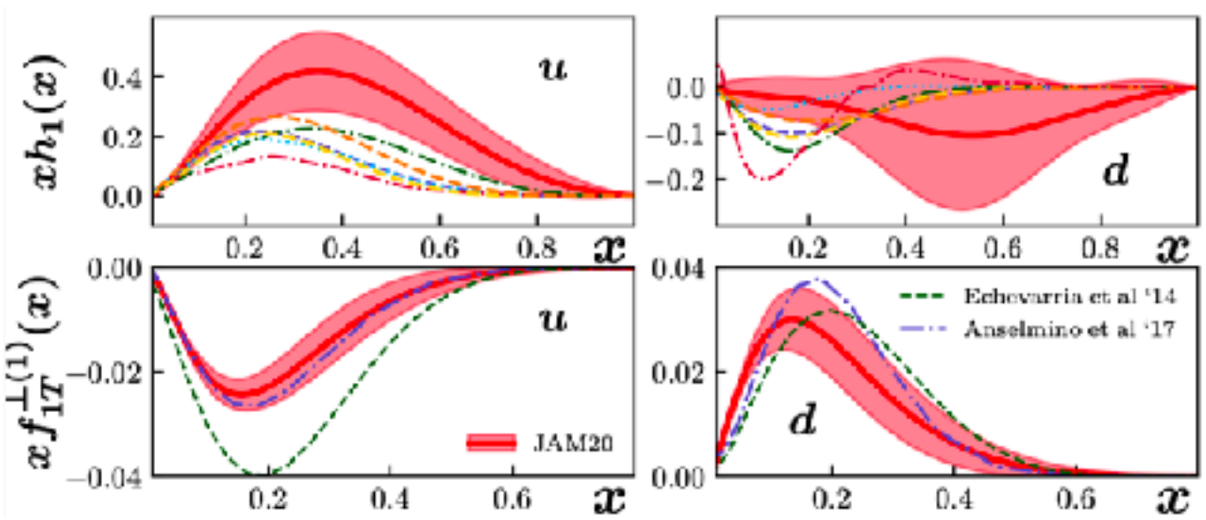
OTHER TASKS RELATED WITH THE PARTONIC STRUCTURE

Tensor structure of deuteron:

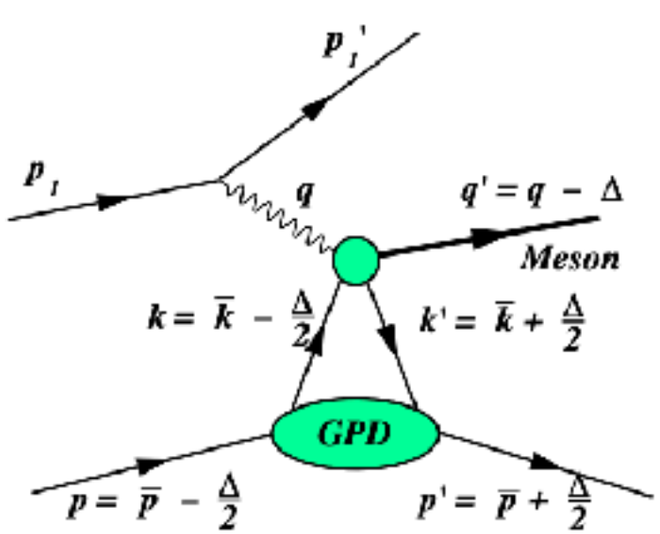


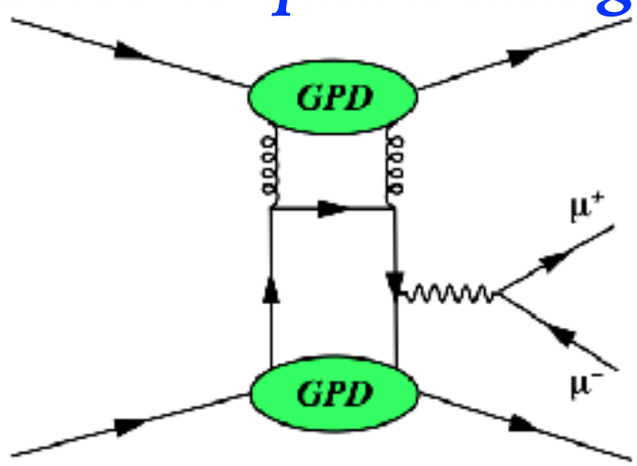
New structure functions: b_1, b_2, b_3, b_4

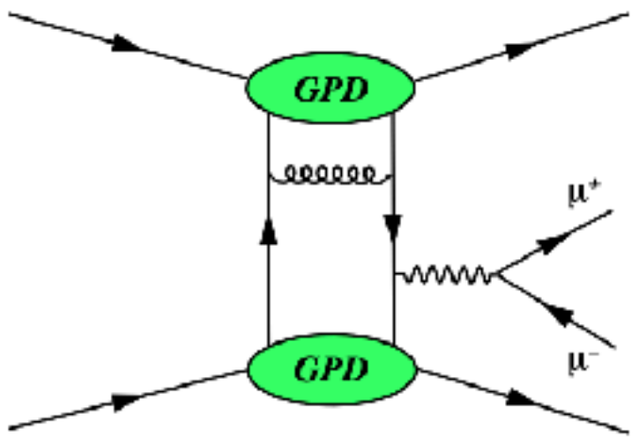
STSA with light hadrons — contribution to global fit of quark TMDs



Access to quark and gluon GPDs







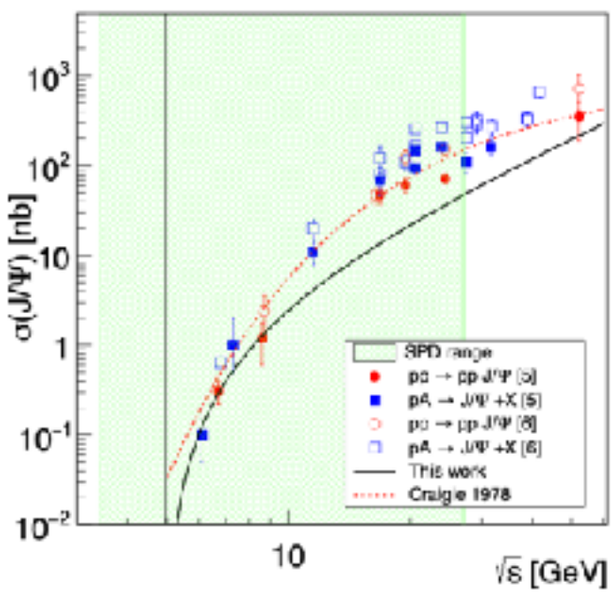
arXiv:2102.08477

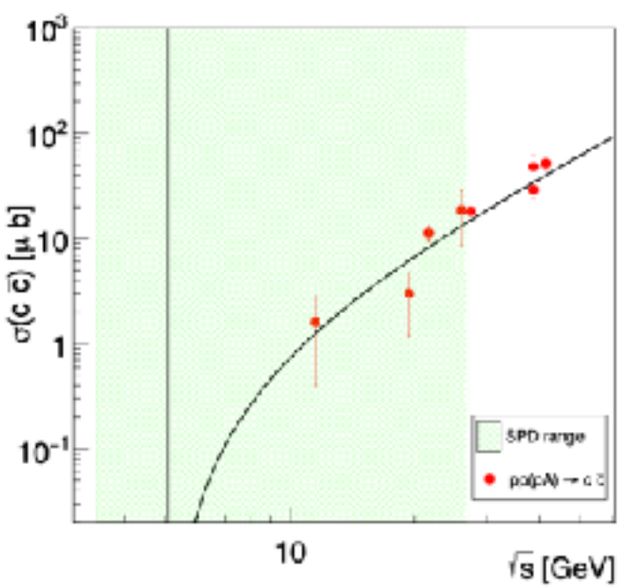
PHYSICS OF THE FIRST STAGE OF SPD RUNNING

Non-perturbative QCD — *Perturbative QCD*

$\sqrt{s}$

- Spin effects in p-p, p-d and 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





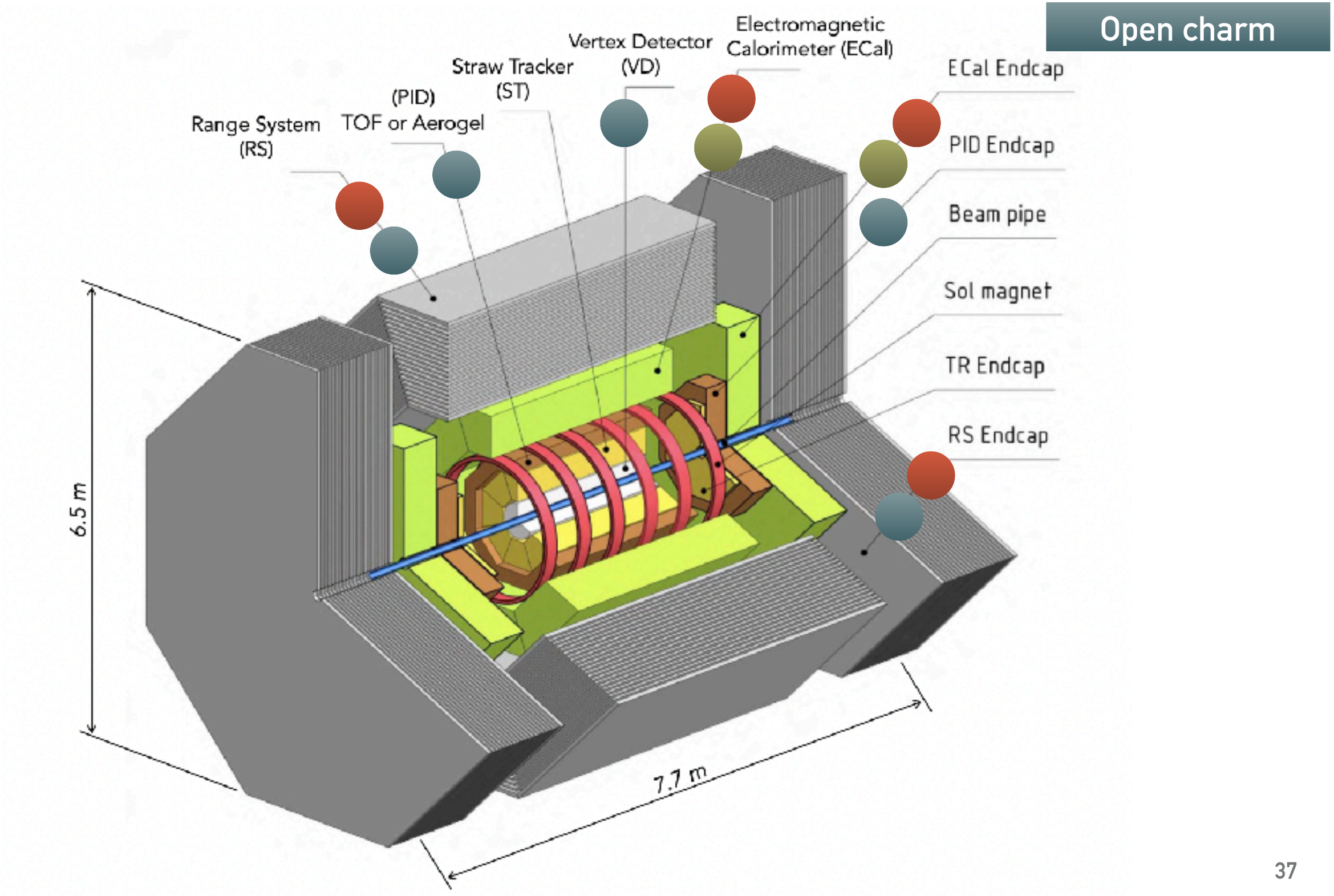
- Auxiliary measurements for astrophysics
- …

SPD DETECTOR

Charmonia

Prompt photons

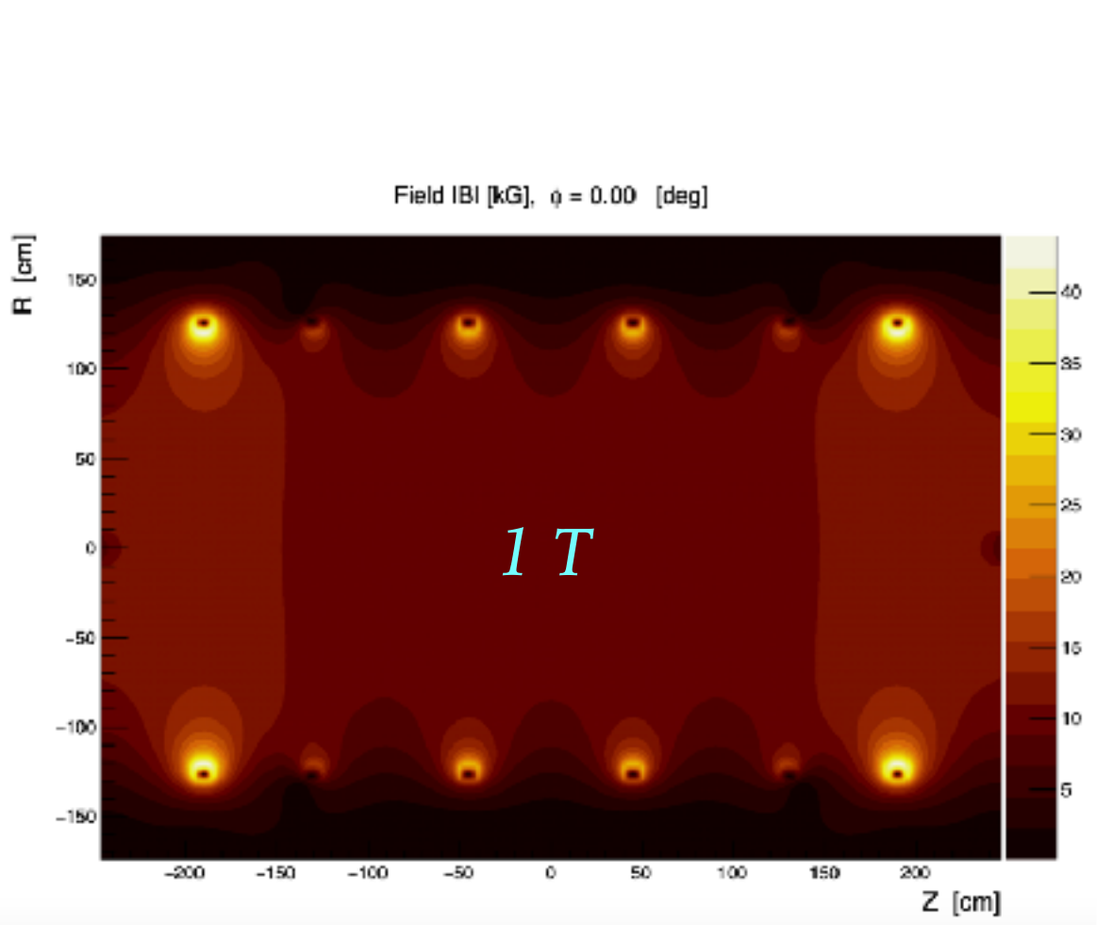
Open charm

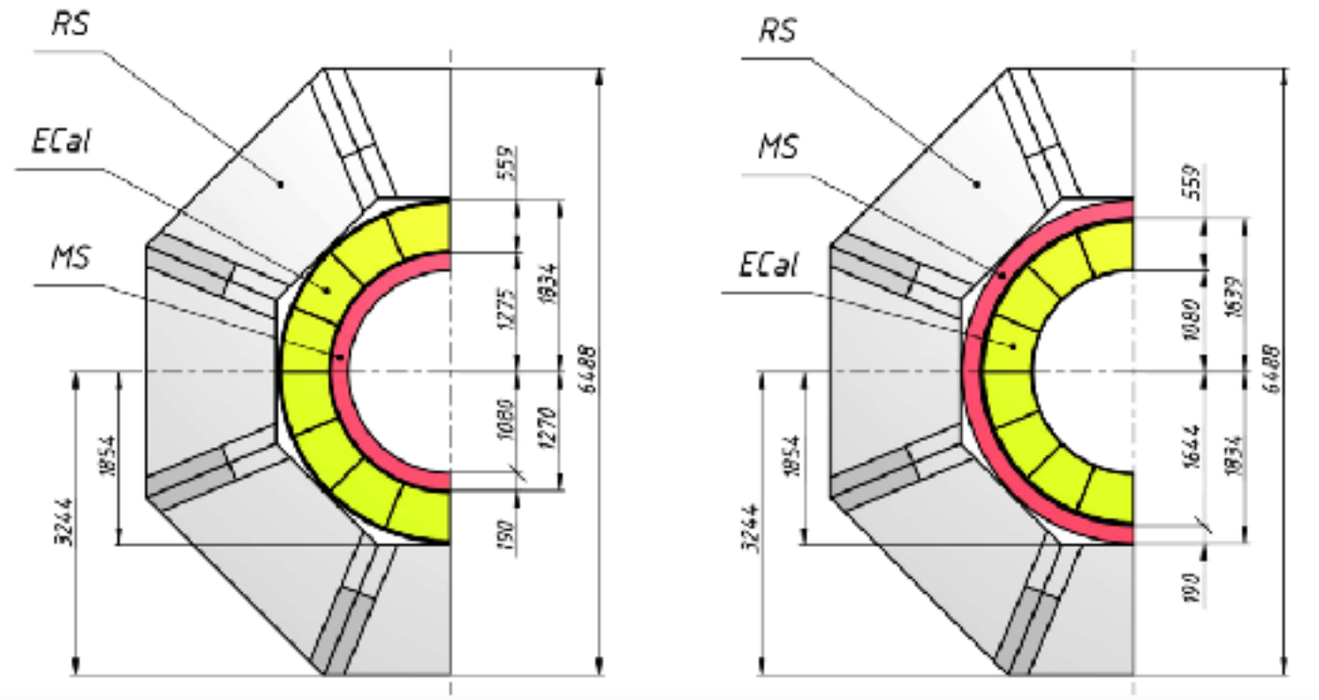


MAGNETIC SYSTEM

6 superconductive solenoidal coils inside the ECAL:

- *compact*
- *1 T at the beam axis*
- *Z-optimization*





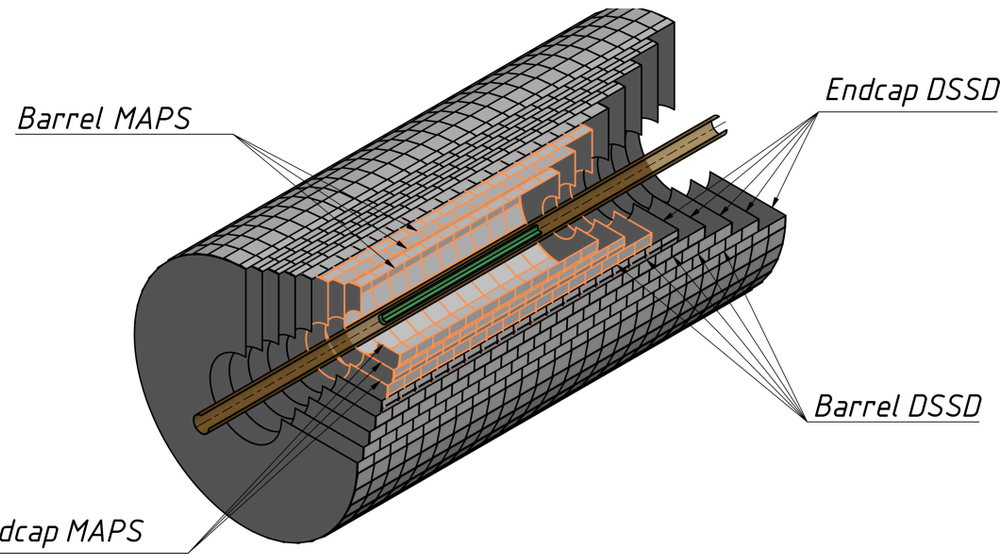
Still 2 options

TRACKING SYSTEM

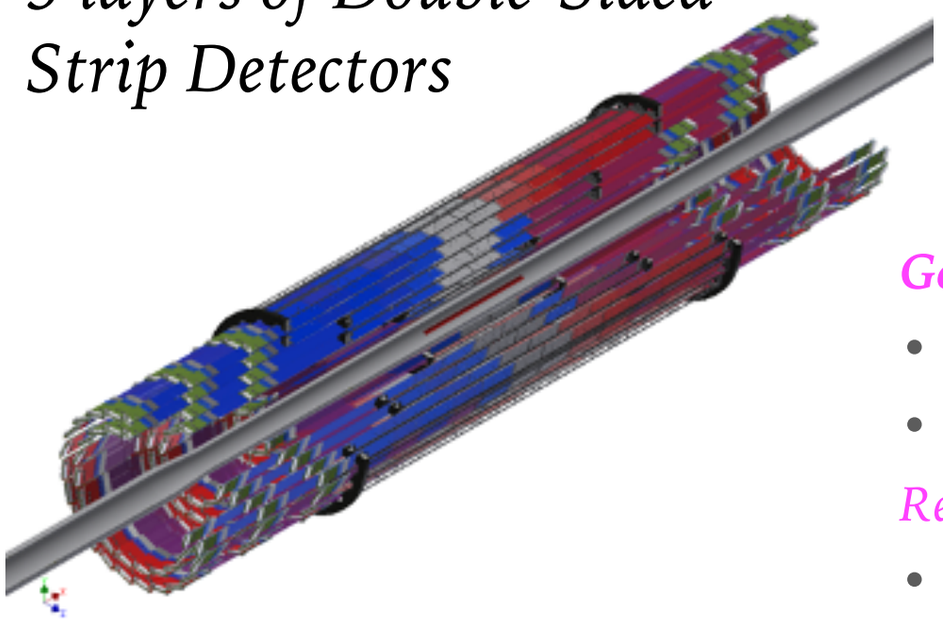
3 internal layers in barrel replaced by MAPS

Vertex Detector

Two options:



5 layers of Double-Sided Strip Detectors



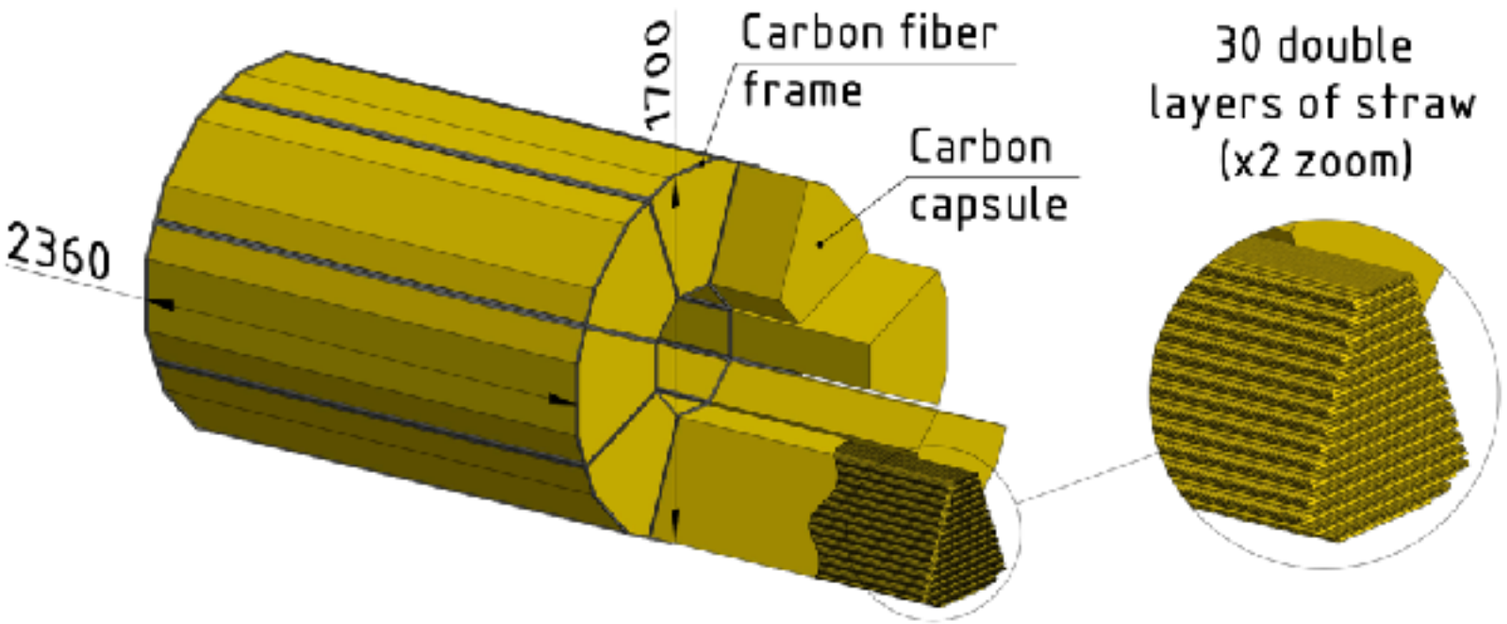
Goals:

- *Reconstruction of secondary vertices for D-mesons decay*
- *Participation in track reconstruction and momentum measurement*

Requirements:

- *Spatial resolution <100 μm*
- *Low material budget*
- *Has to be installed as close as possible to the IP*

Straw tracker



Goals:

- *Track reconstruction and momentum measurement*
- *Participation in PID via dE/dx measurement*

Requirements:

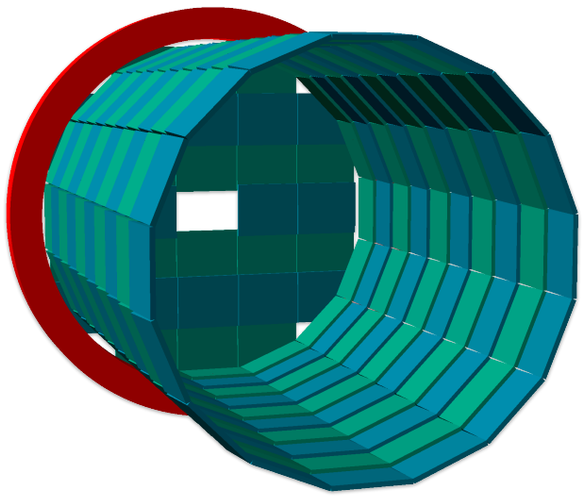
- *Spatial resolution ~150 μm*
- *Low material budget*
- *Operation in magnetic field of about 1 T*

some R&D is still needed

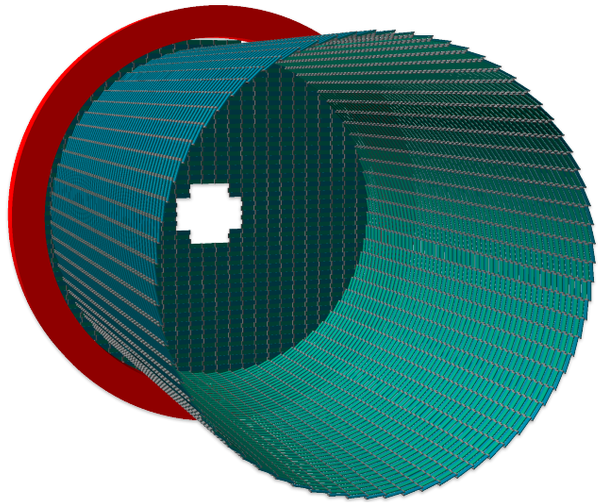
PARTICLE IDENTIFICATION SYSTEM

TOF system

mRPC-based



Scintillator-based



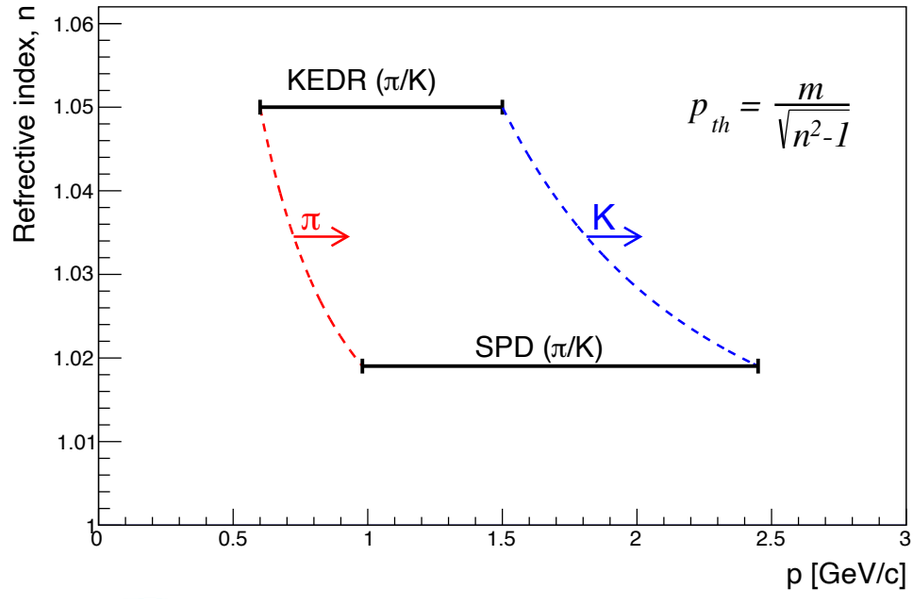
Goals:

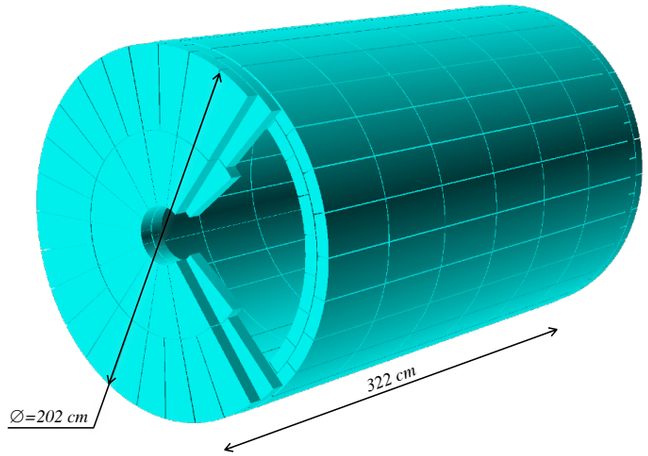
- *π/K separation up to ~1.5 GeV*
- *K/p separation*
- *t_0 determination*

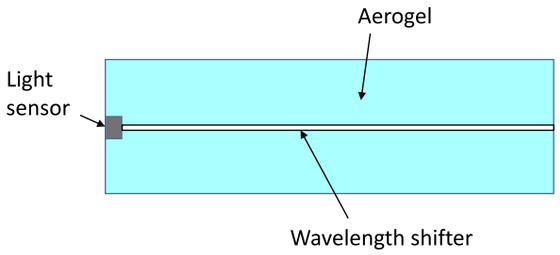
Requirements:

- *Time resolution ~60-70 ps*

Aerogel-based PID







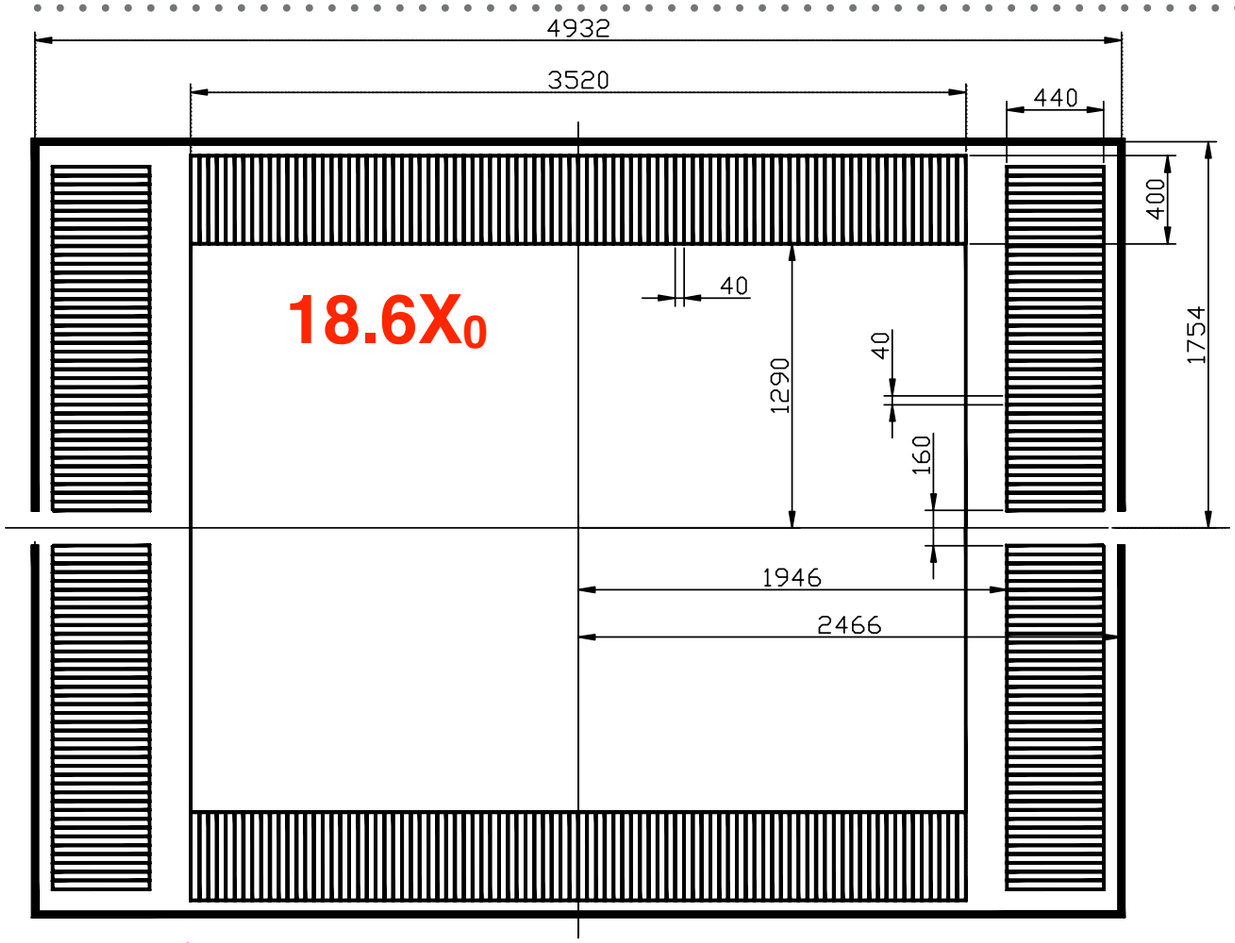
Goals:

- *π/K separation up to 2.5 GeV range*

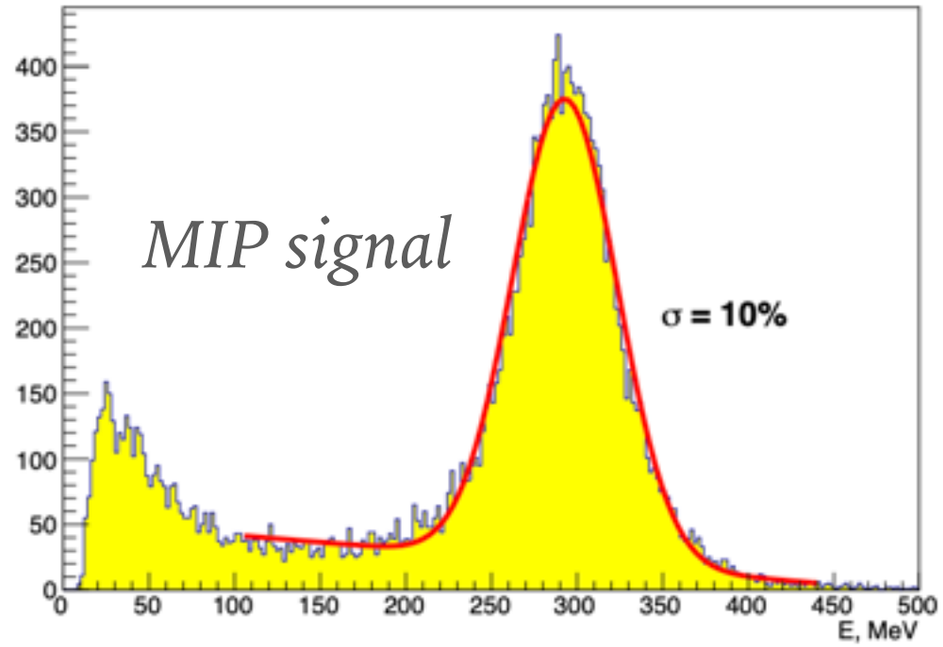
Requirements:

- *We should have enough light!*

ELECTROMAGNETIC CALORIMETER



"Shashlyk"-type: 200 layers of scintillator (1.5 mm) and Pb (0.5 mm)



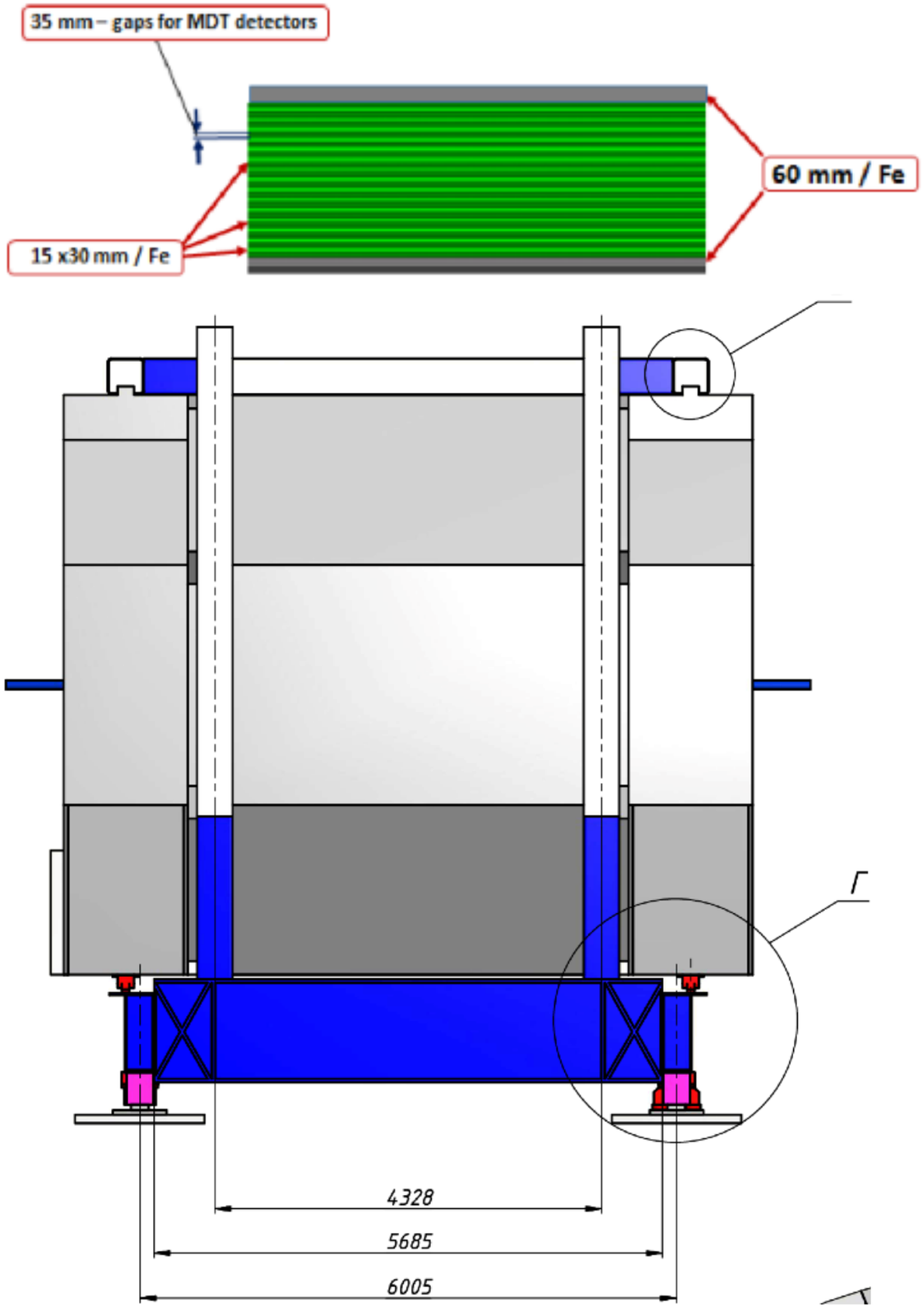
Goals:

- *Detection of prompt photons, photons from π^0, η and χ_c decays*
- *Identification of electrons and positrons, participation in muon identification*

Requirements:

- *Granularity ~4 cm*
- *Low energy threshold (~50 MeV)*
- *Energy resolution* $\sim 5\,\%/\sqrt{E}$

RANGE (MUON) SYSTEM



Goals:

- *Muon identification*
- *Rough hadron calorimetry*
- *Yoke of the magnetic system*

Requirements:

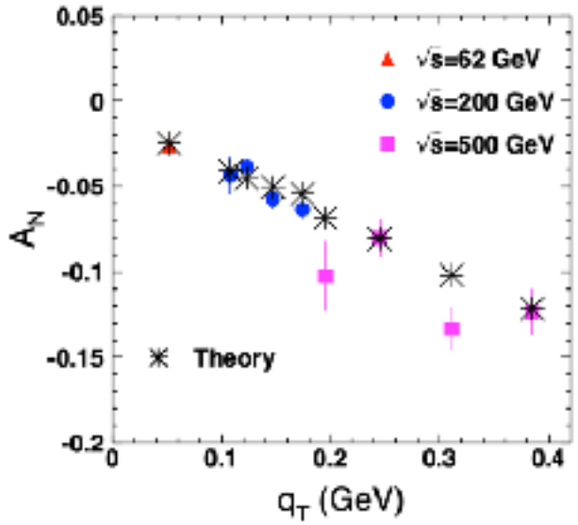
- *should have at least* $4\lambda_I$

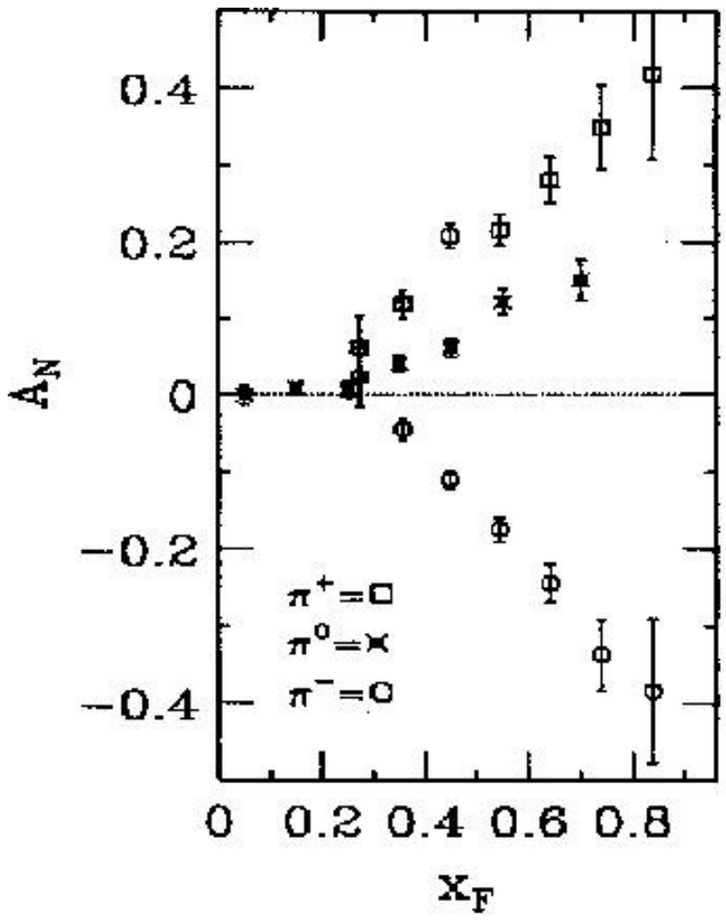
Event examples at 5 GeV/c

LOCAL POLARIMETRY AND LUMINOSITY CONTROL

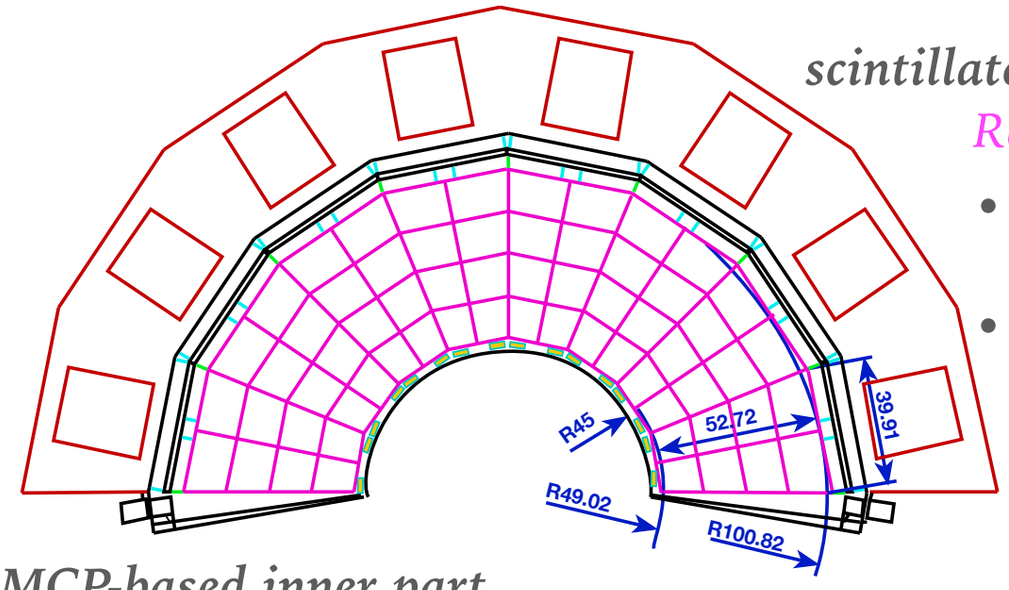
Local polarimetry

- *Charged particles in BBC*
- *π^0 in the end-cap part of ECAL*
- *Neutrons in ZDC*





Beam-Beam Counter

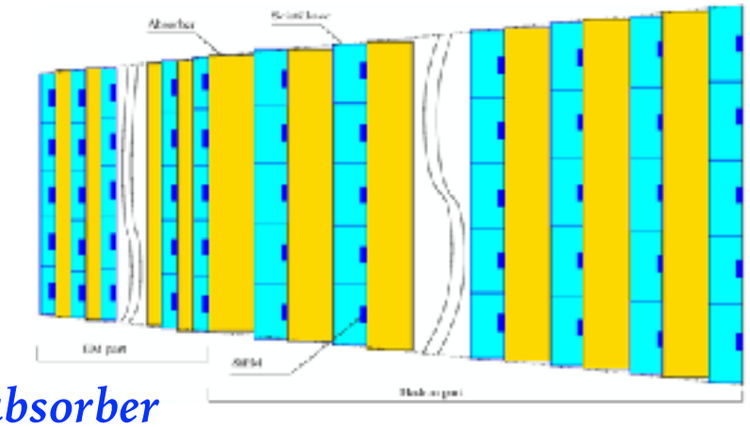


MCP-based inner part

scintillator-based outer part

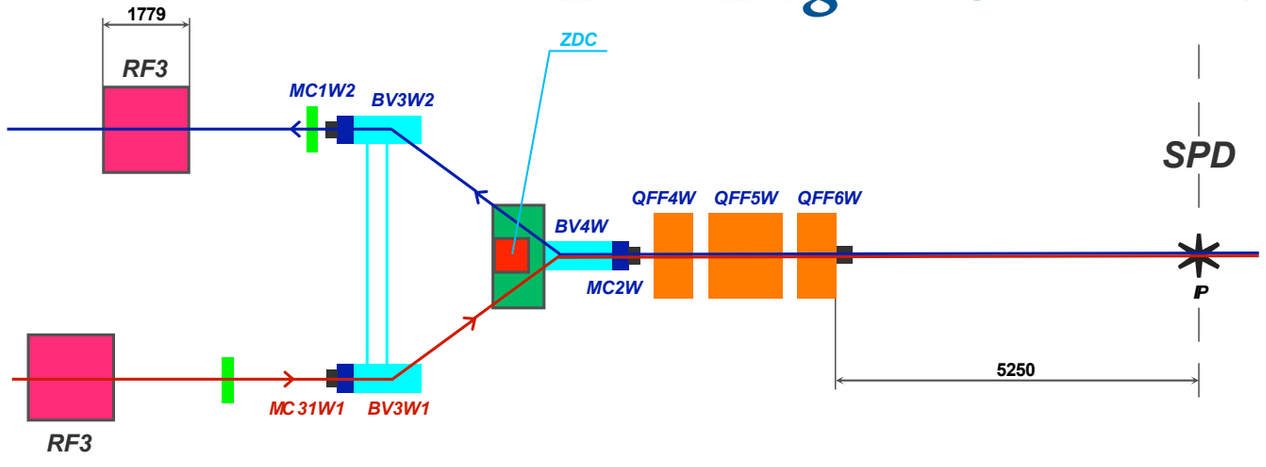
Requirements:

- *Operation inside the beam pipe (inner part)*
- *Time resolution ~1 ns (inner) and ~400 ps (outer part)*



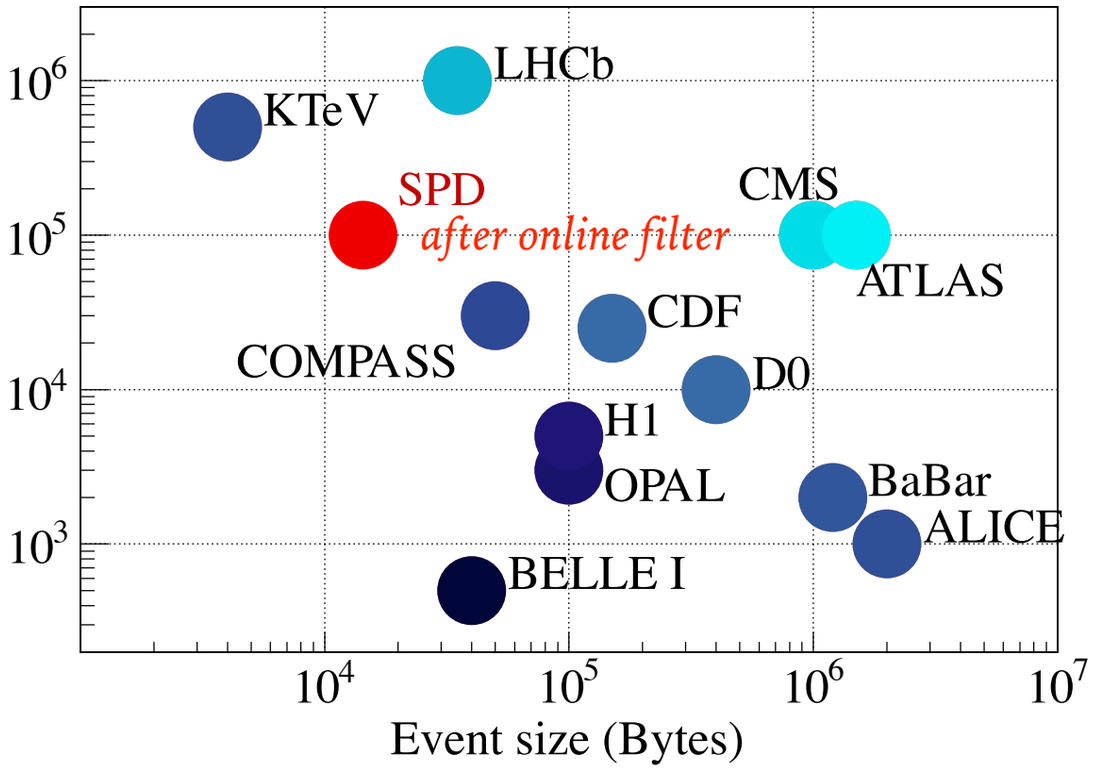
W-absorber

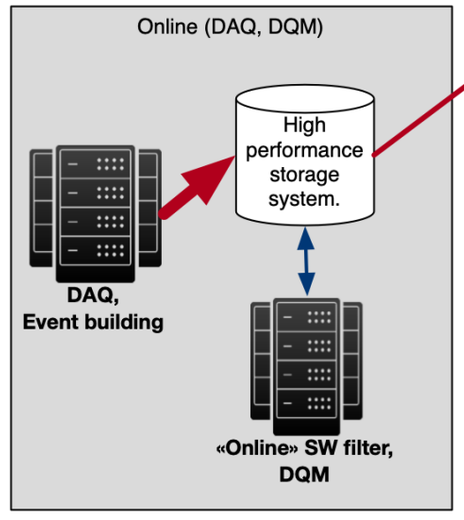
Zero Degree Calorimeter

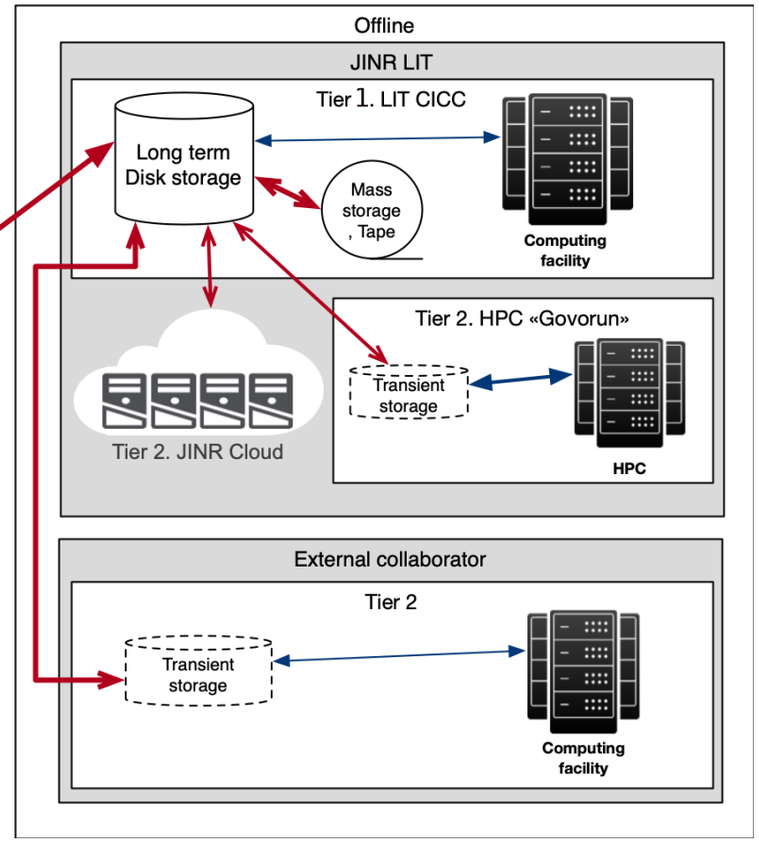


DAQ & COMPUTING

No hardware triggers to avoid possible bias!

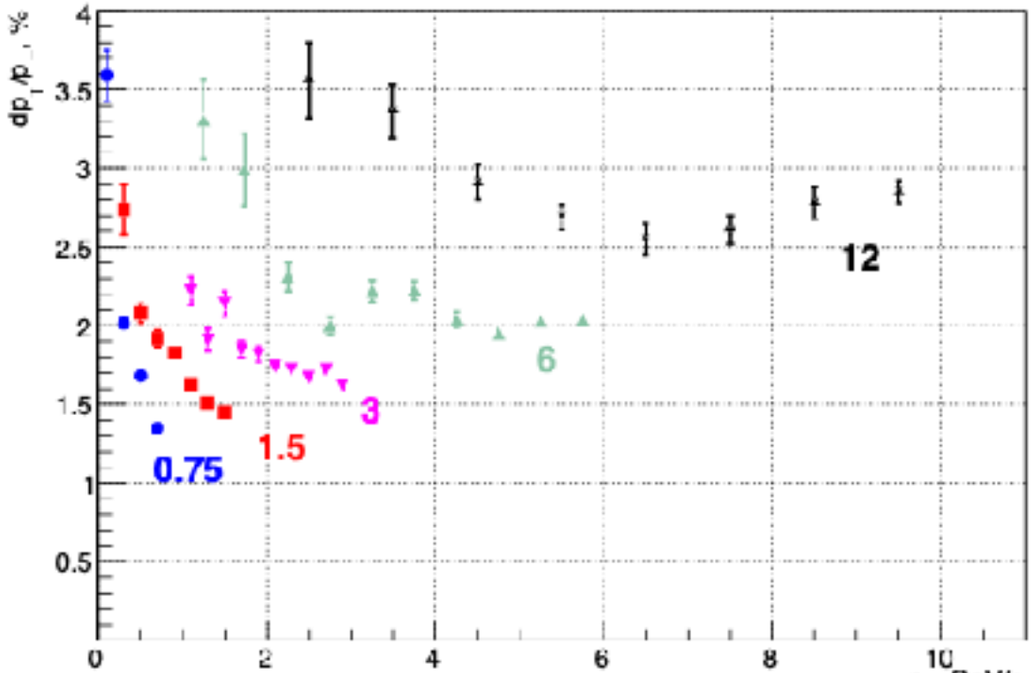


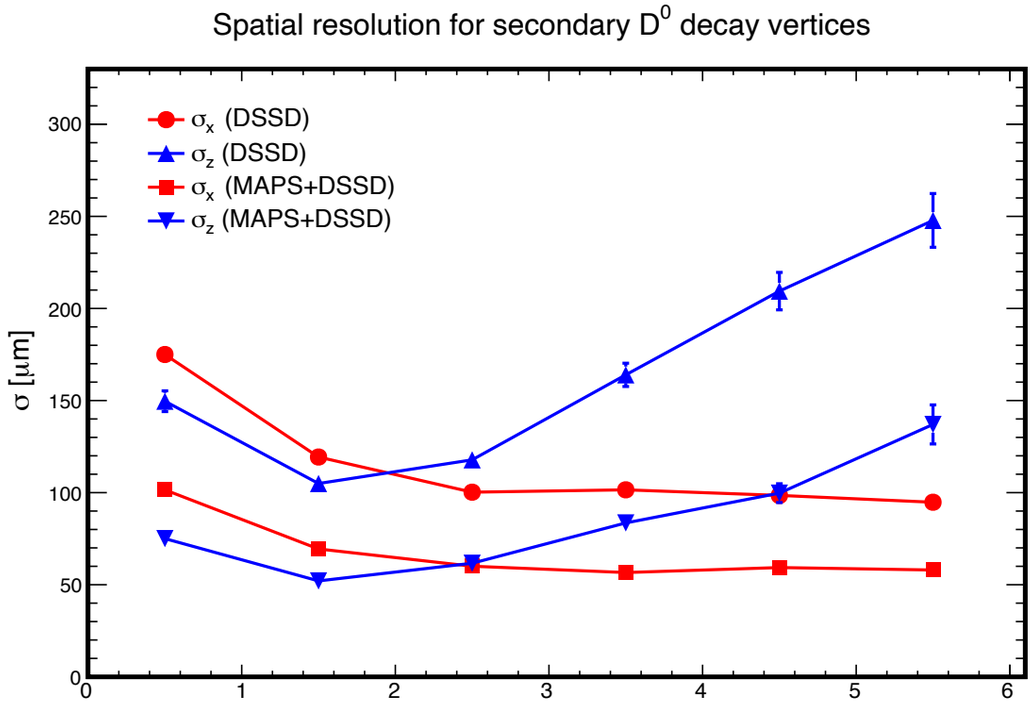


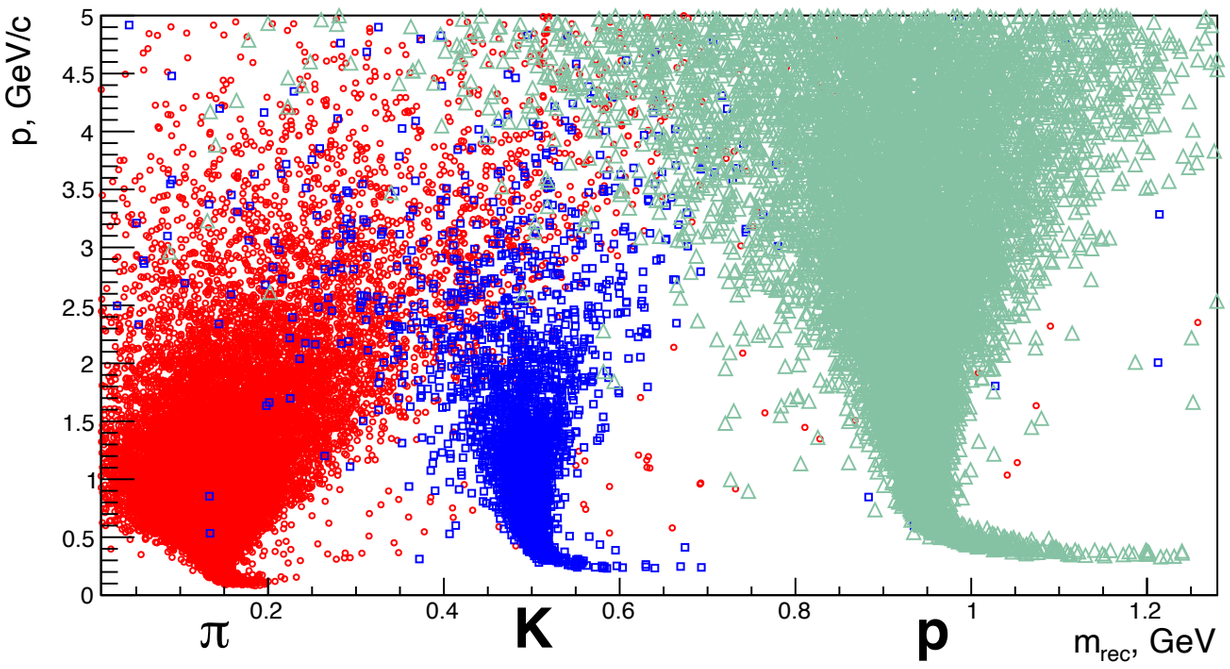


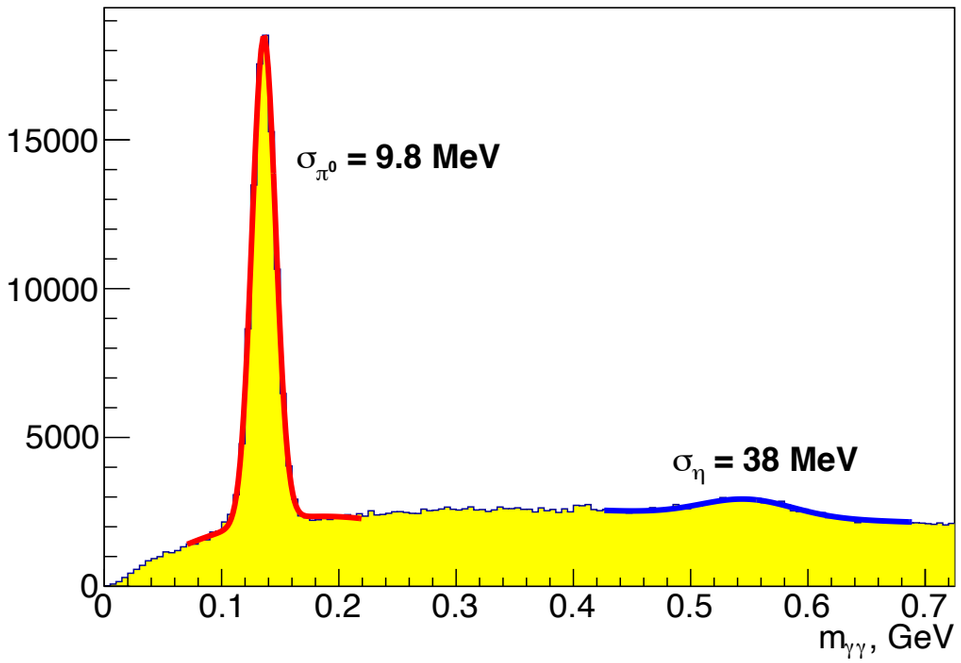
	CPU [cores]	Disk [PB]	Tape [PB]
Online filter	6000	2	none
Offline computing	30000	5	9 per year

DETECTOR PERFORMANCE

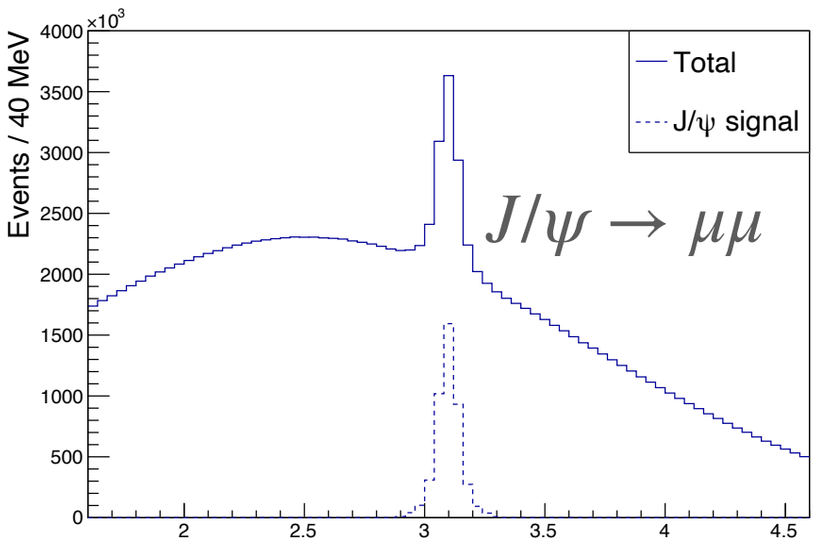


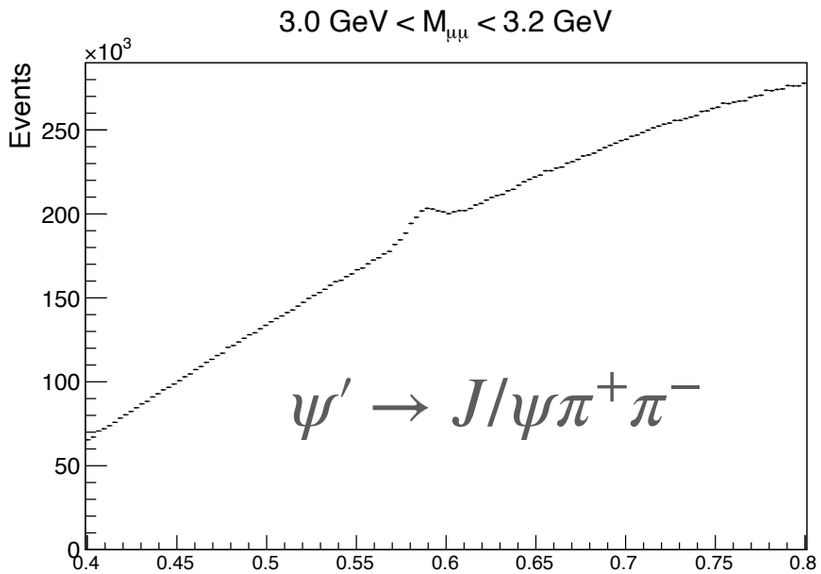


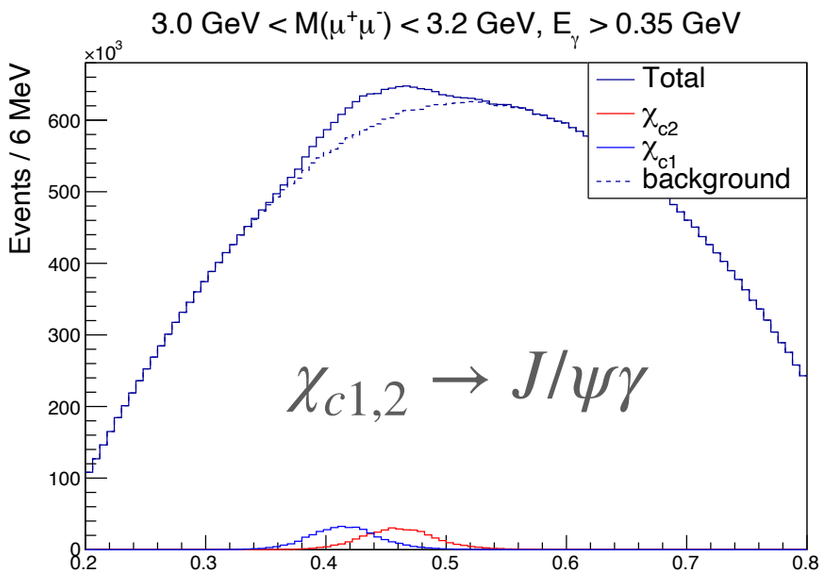


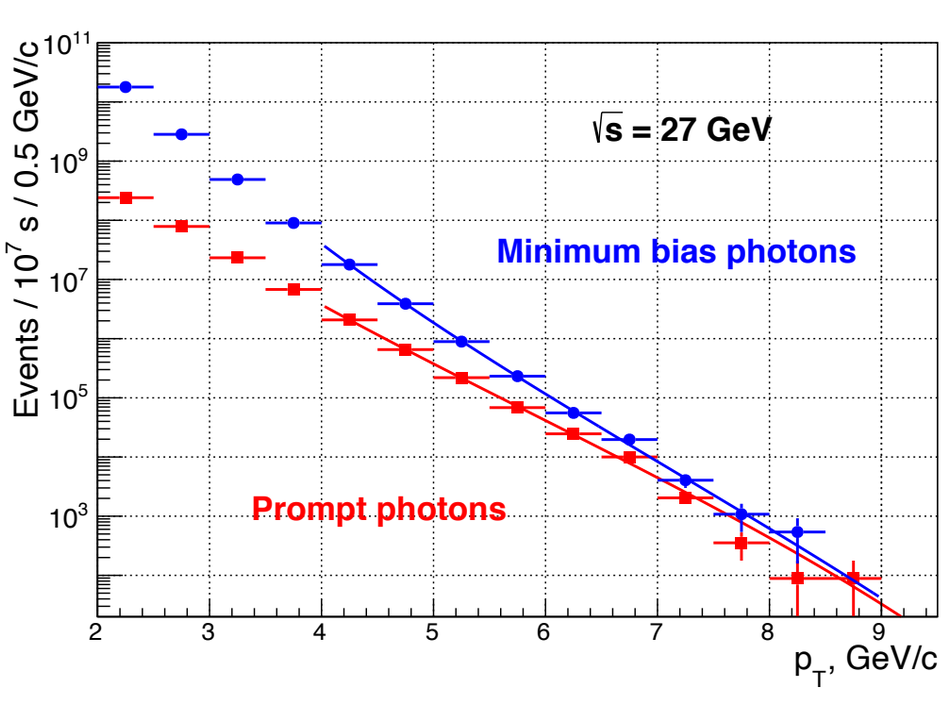


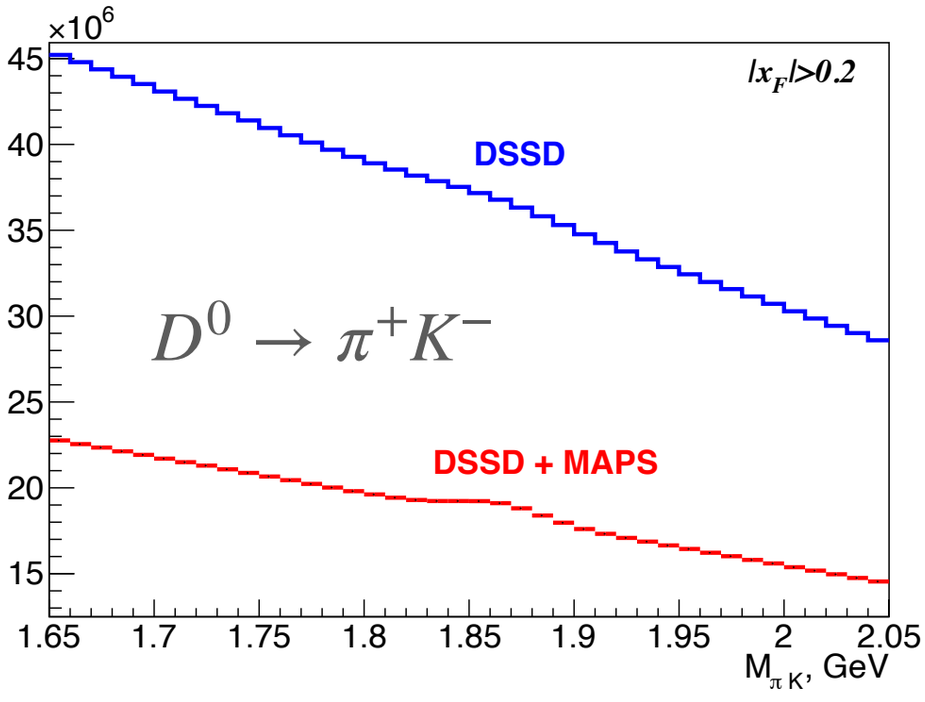
PHYSICS PERFORMANCE: GLUON PROBES (1 YEAR=10^7 S)



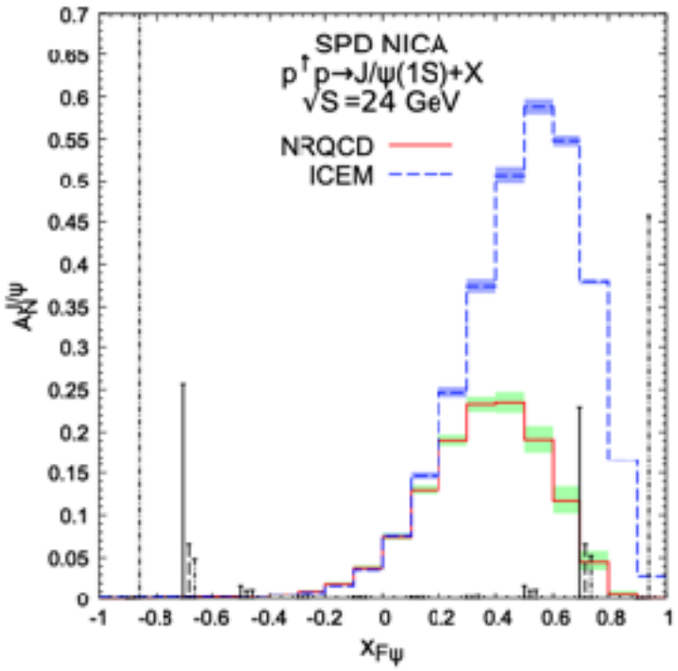




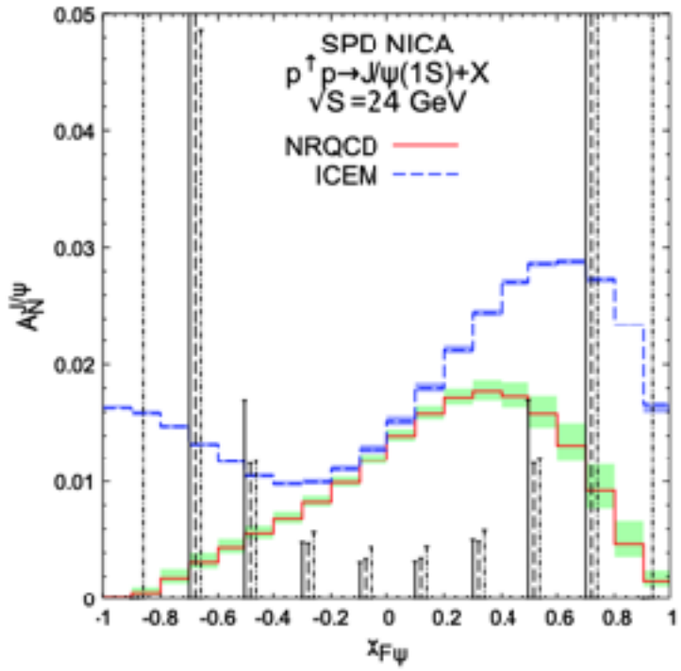


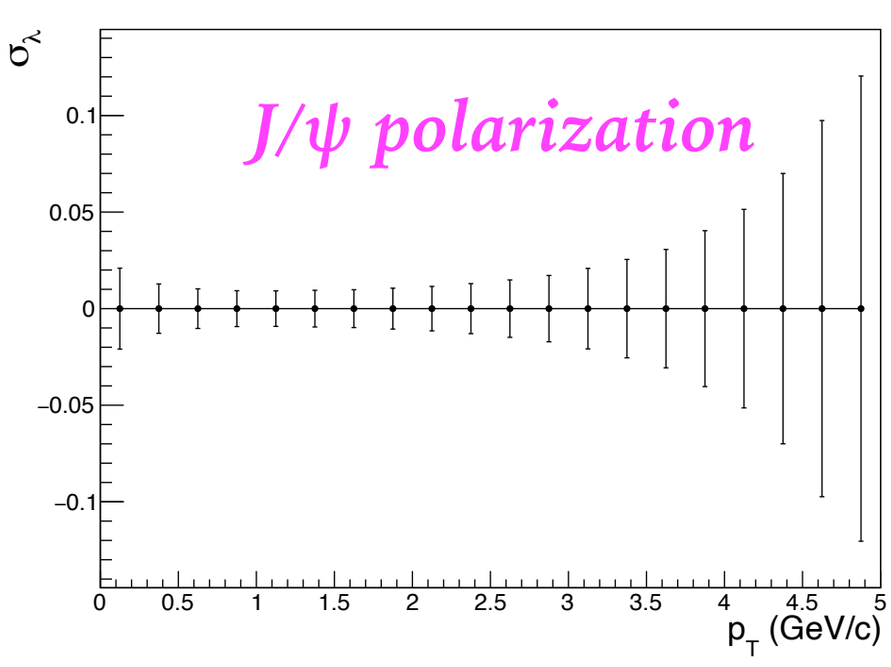


PHYSICS PERFORMANCE: ACCURACIES



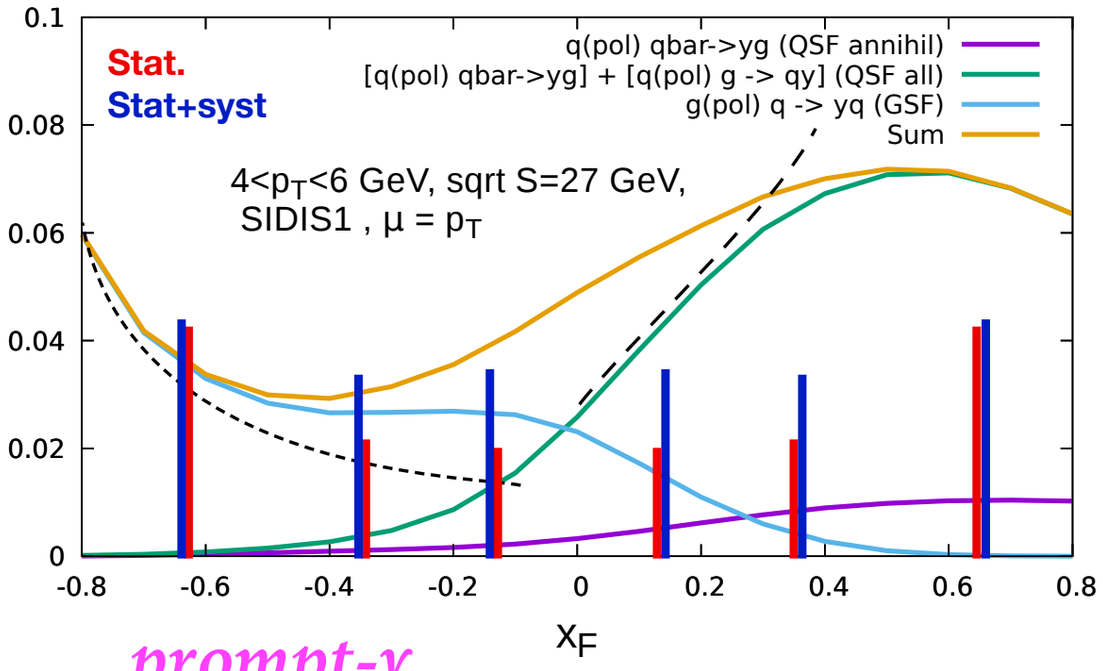
J/ψ



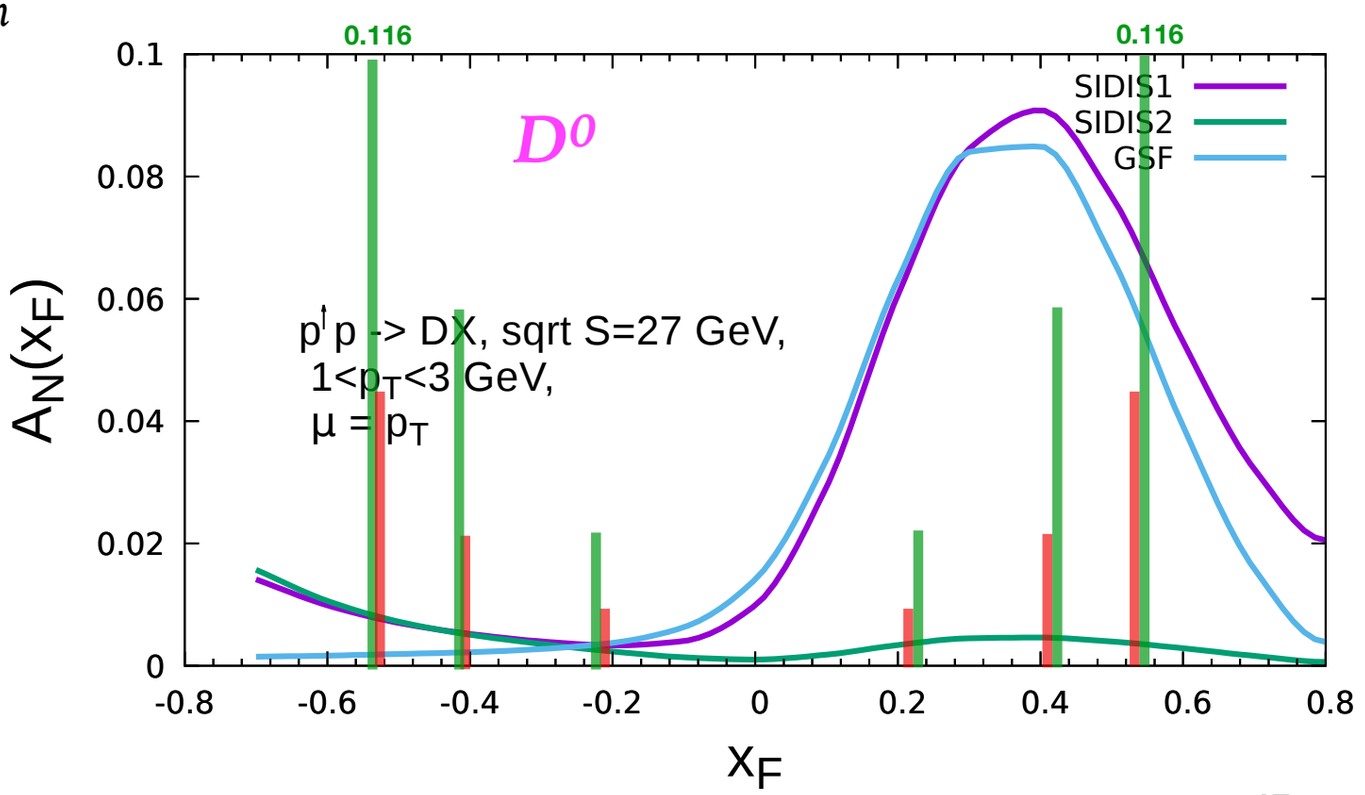


J/ψ polarization

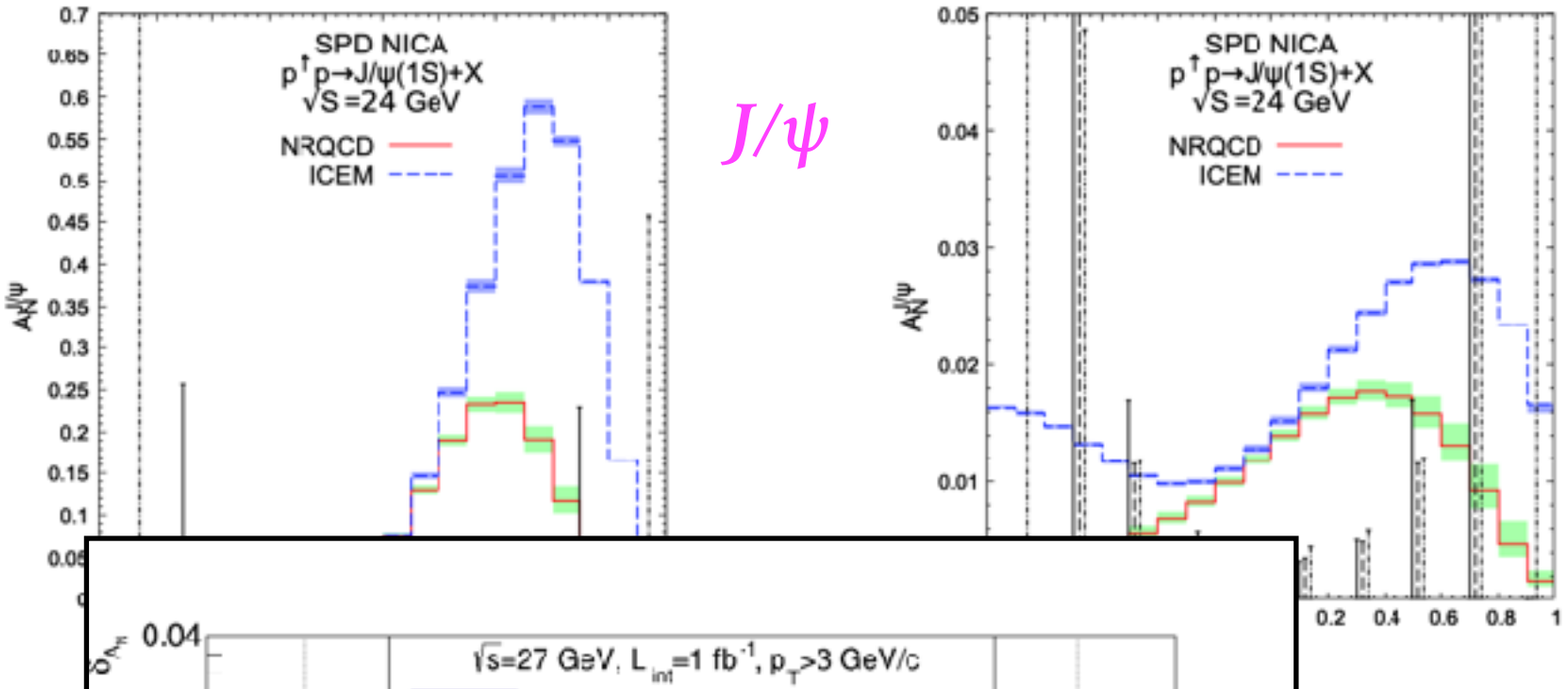
Different inputs for gluon Sivers function



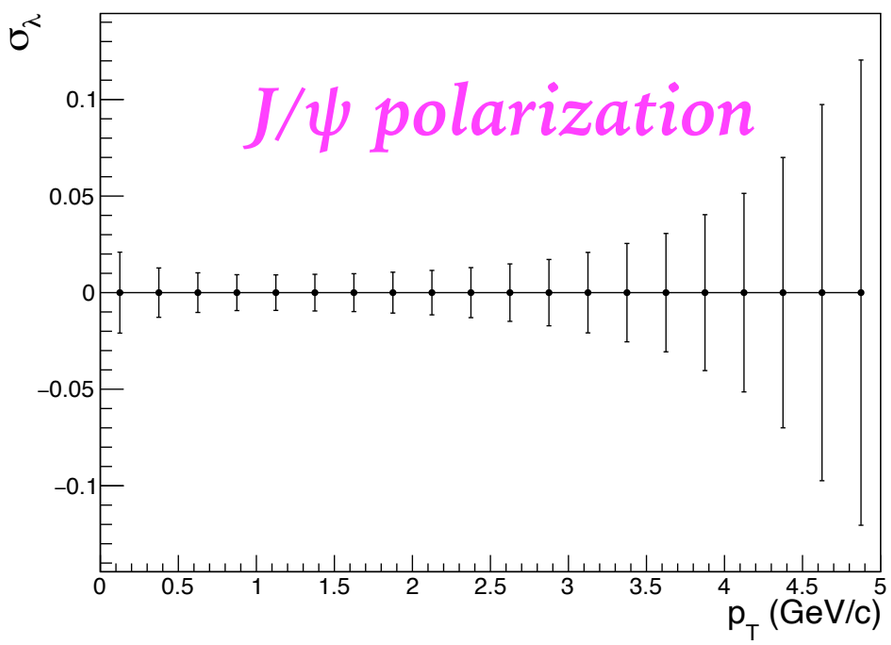
prompt-γ



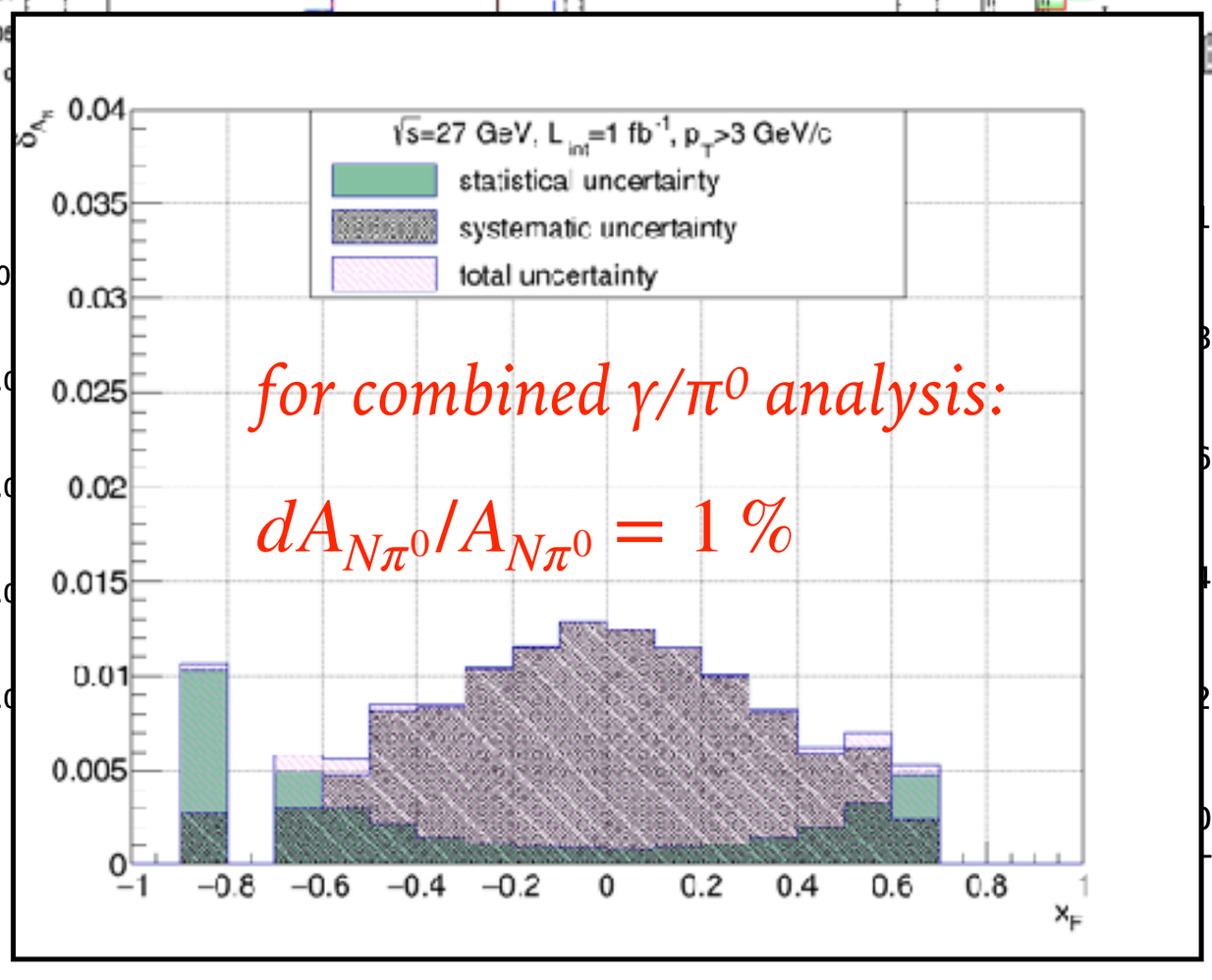
PHYSICS PERFORMANCE: ACCURACIES



J/ψ

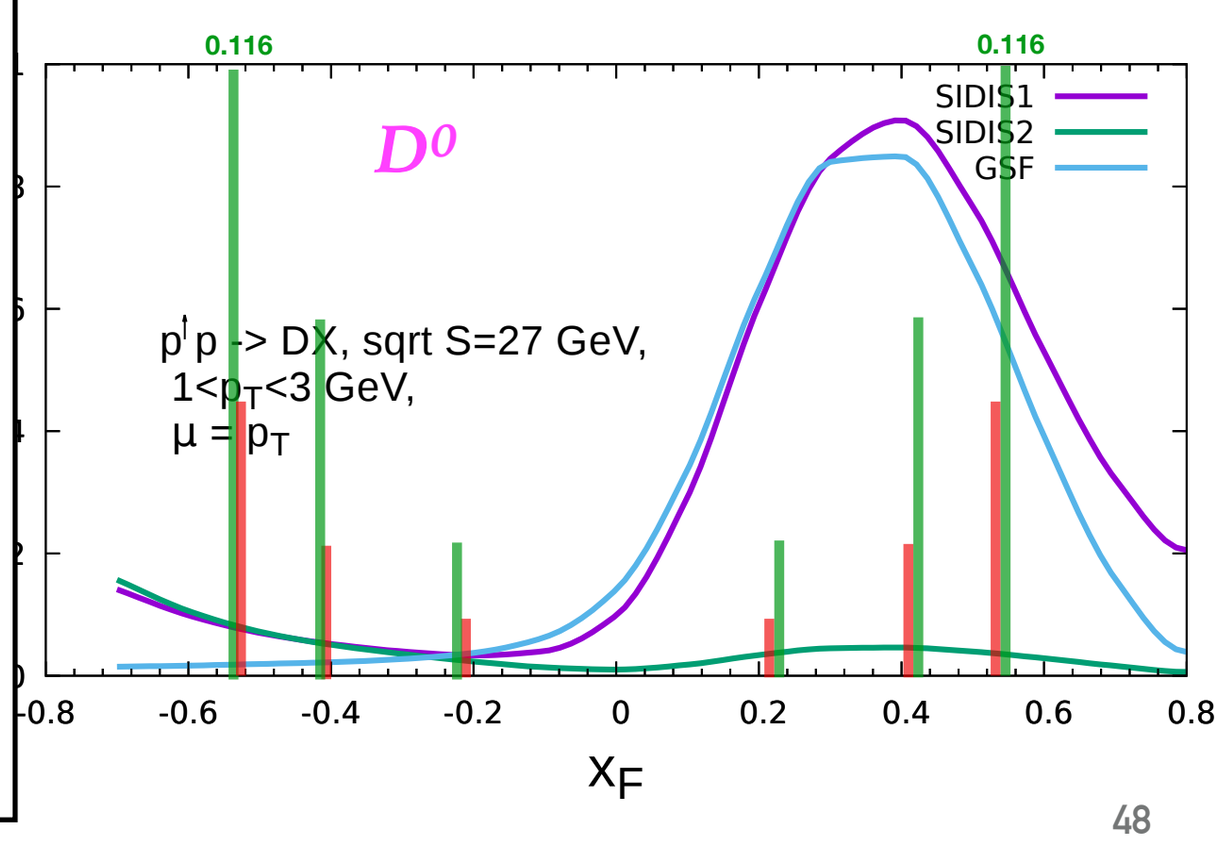


J/ψ polarization

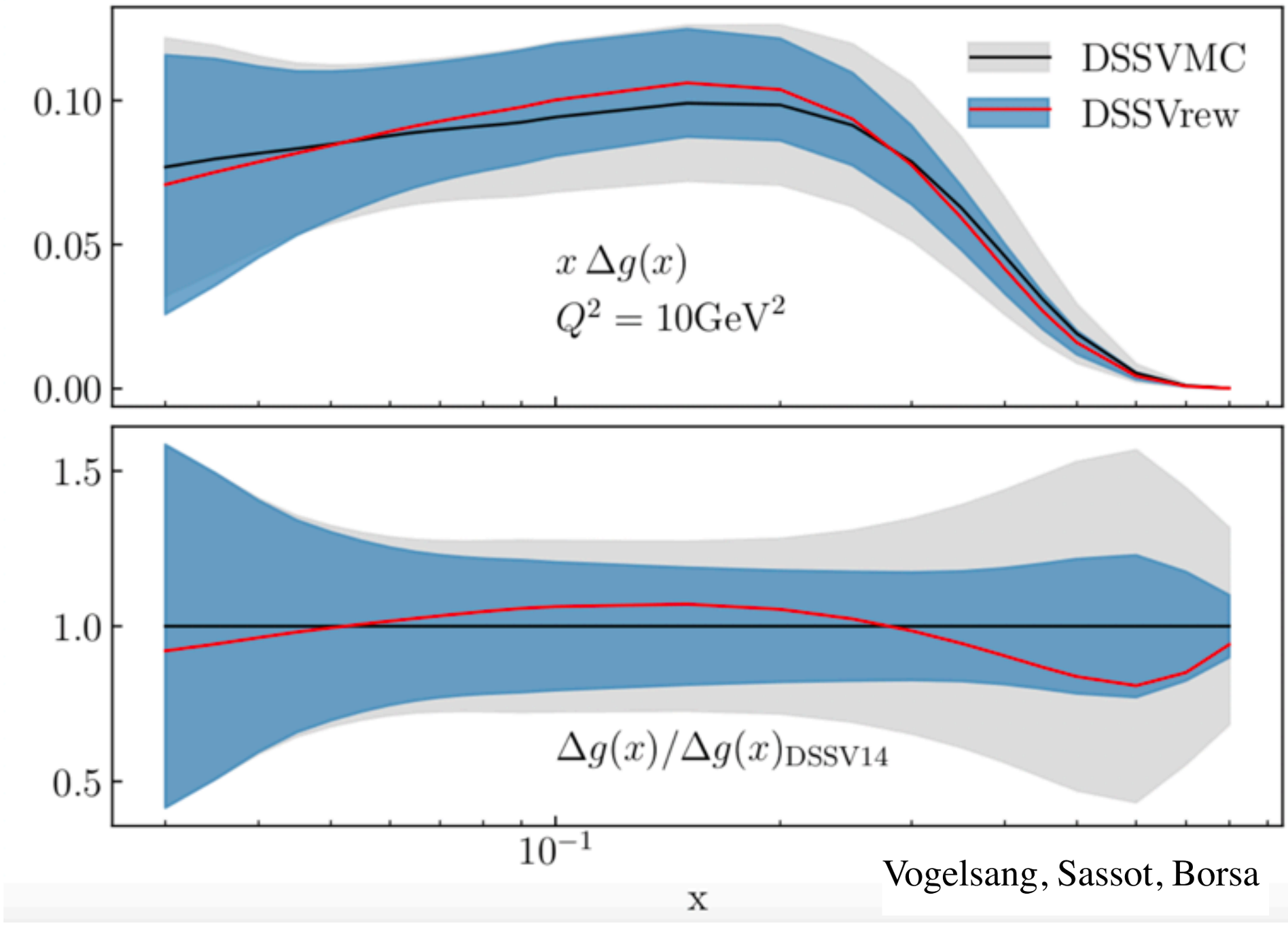


for combined γ/π⁰ analysis:

$dA_{N\pi^0}/A_{N\pi^0} = 1\,\%$



IMPACT OF SPD MEASUREMENTS TO THE WORLD DATA FOR Δg(x)



Vogelsang, Sassot, Borsa

TENTATIVE RUNNING PLAN

Physics goal	Required time	Experimental conditions
First stage		
Spin effects in p-p scattering dibaryon resonanses	0.3 year	$p_{L,T}$-$p_{L,T}$, $\sqrt{s}$ <7.5 GeV
Spin effects in p-d scattering, non-nucleonic structure of deuteron, $\bar{p}$ yield	0.3 year	d_{tensor}-p, $\sqrt{s}$ <7.5 GeV
Spin effects in d-d scattering hypernuclei	0.3 year	d_{tensor}-d_{tensor}, $\sqrt{s}$ <7.5 GeV
Hyperon polarization, SRC, ... multiquarks	together with MPD	ions up to Ca
Second stage		
Gluon TMDs, SSA for light hadrons	1 year	p_T-p_T, $\sqrt{s}$ =27 GeV
TMD-factorization test, SSA, charm production near threshold, onset of deconfinment, $\bar{p}$ yield	1 year	p_T-p_T, 7 GeV< $\sqrt{s}$ <27 GeV (scan)
Gluon helicity, ...	1 year	p_L-p_L, $\sqrt{s}$ =27 GeV
Gluon transversity, non-nucleonic structure of deuteron, "Tensor porlarized" PDFs	1 year	d_{tensor}-d_{tensor}, $\sqrt{s_{NN}} = 13.5$ GeV or/and? d_{tensor}-p_T, $\sqrt{s_{NN}} = 19$ GeV

≥ 5 years of data taking

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, EIC) and mesons (COMPASS++/AMBER, EIC).**
- SPD CDR could be found at arXiv:2102.00442 for more details.
- More information could be found at http://spd.jinr.ru