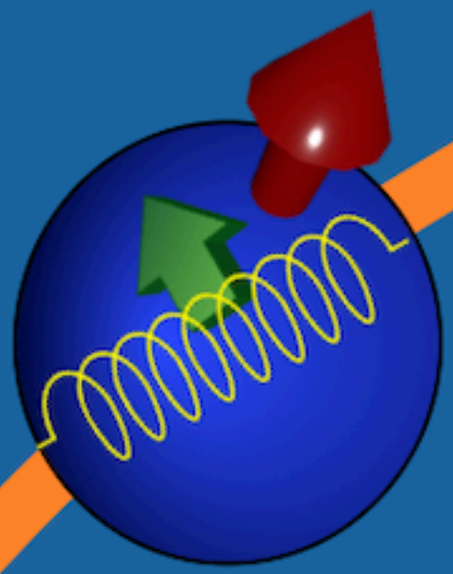
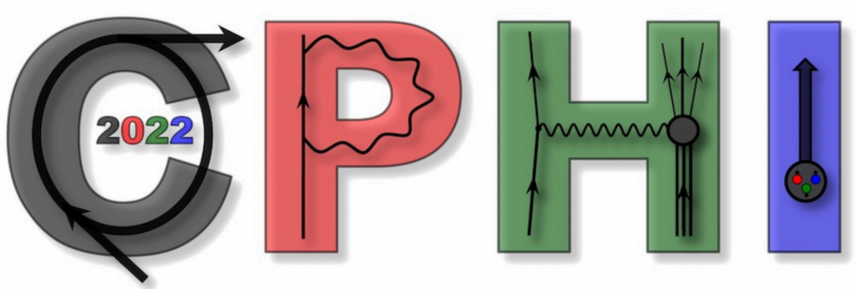


GLUON PHYSICS AT SPD (JINR)

*Alexey Guskov (JINR) on behalf of the **SPD collaboration***

Alexey.Guskov@cern.ch

10.3.2022



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)

SPD AT NICA

NICA - Nuclotron-based Ion Collider fAcility

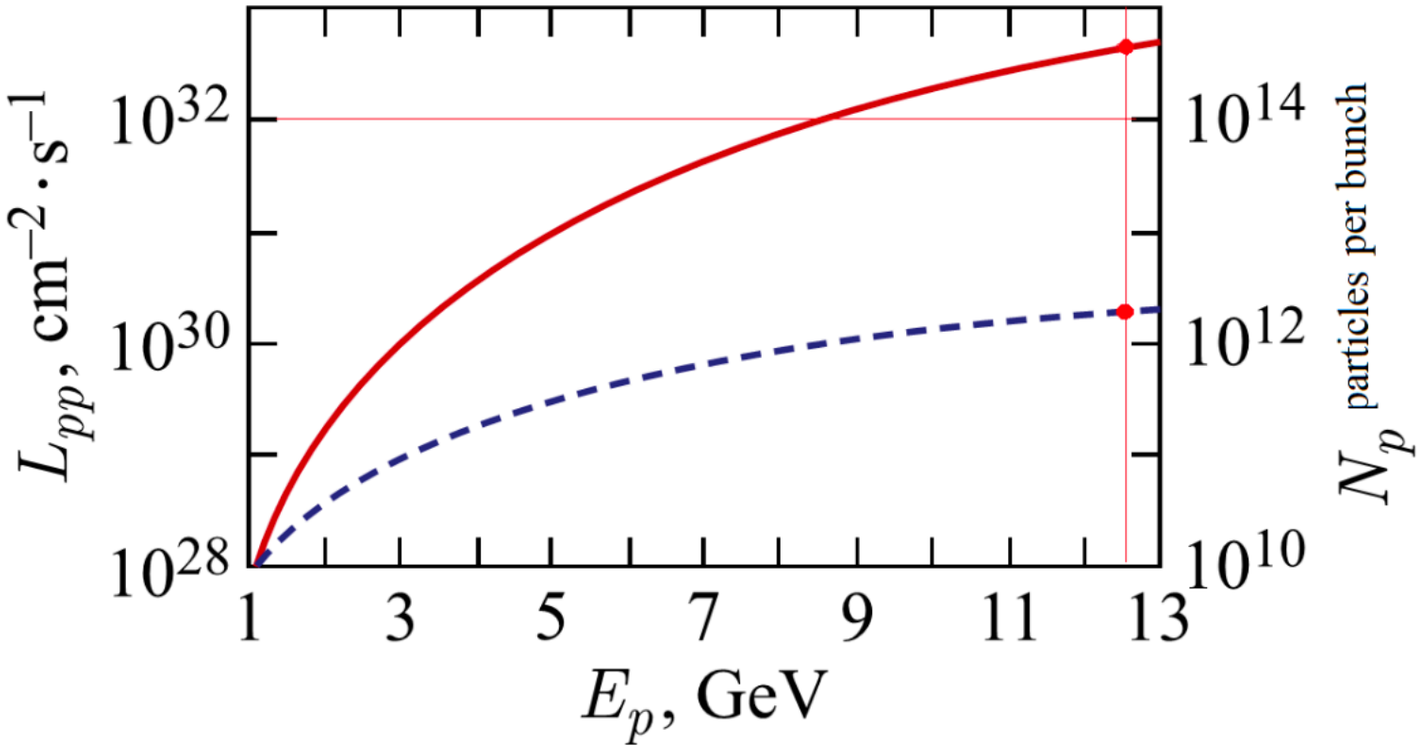
$p^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 27\ GeV$

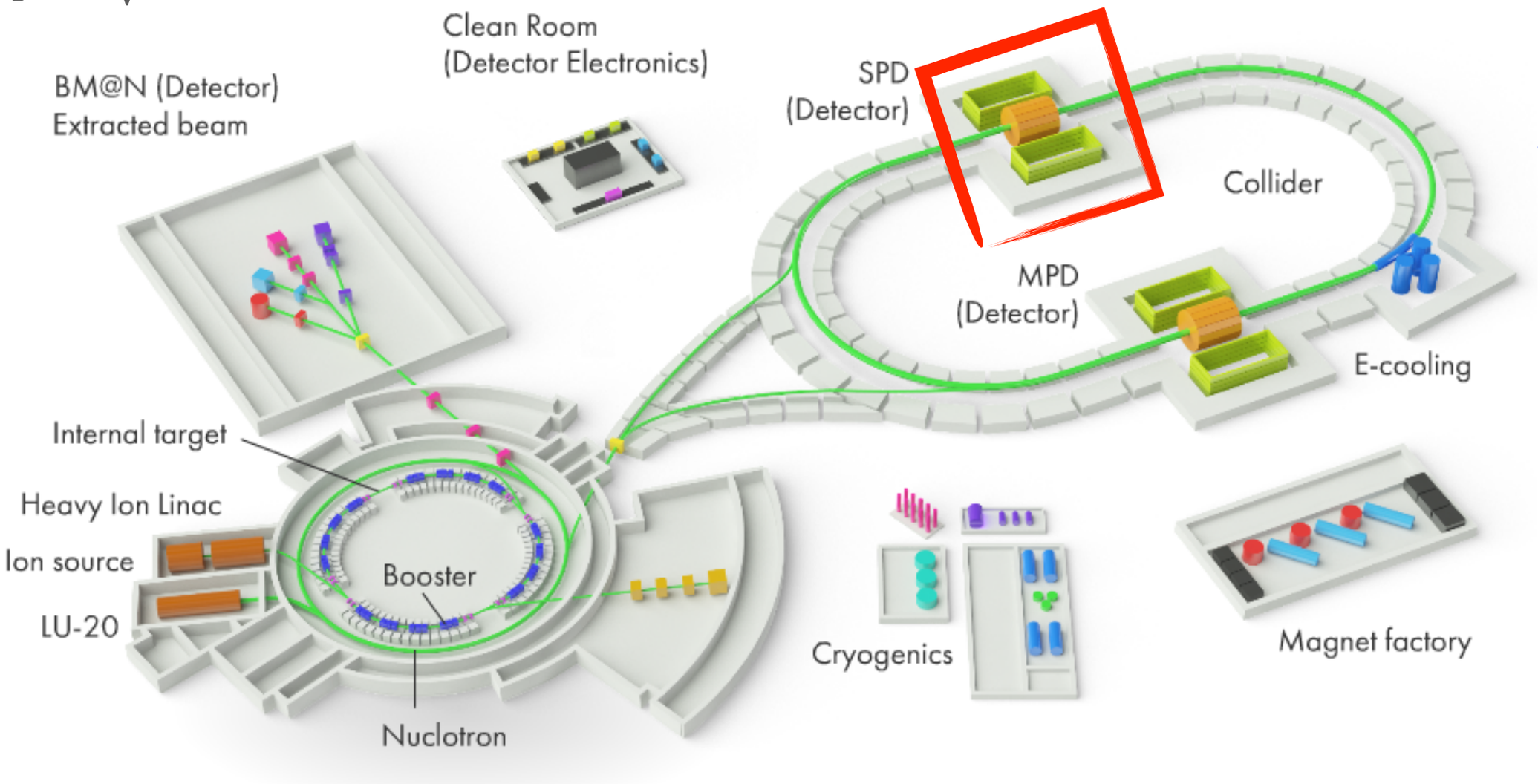
$d^{\uparrow}d^{\uparrow} : \sqrt{s} \leq 13.5\ GeV$

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

U, L, T

|P|>70%



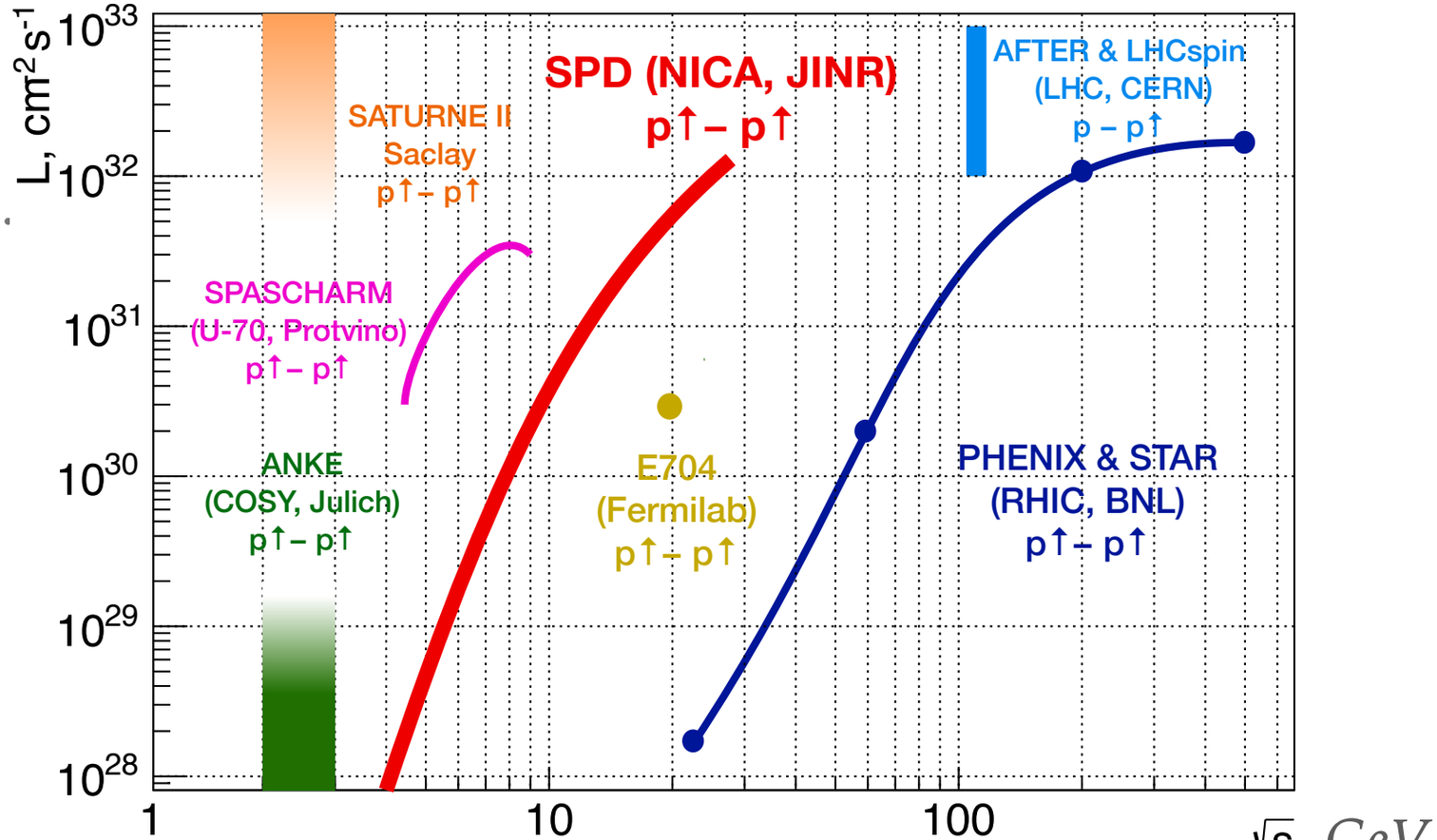


503 m

NICA

SPD & OTHERS

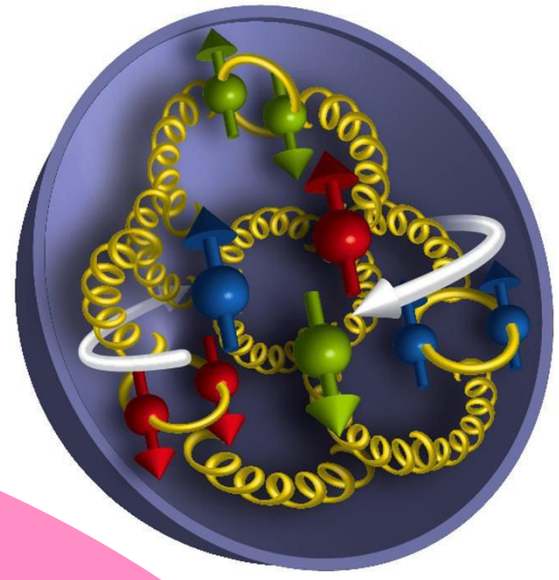
In the $p^{\uparrow}p^{\uparrow}$ mode:



Experimental facility	SPD @NICA	RHIC	EIC	AFTER @LHC	LHCspin
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^{\uparrow}$-$p^{\uparrow}$ $d^{\uparrow}$-$d^{\uparrow}$ $p^{\uparrow}$-d, p-$d^{\uparrow}$	$p^{\uparrow}$-$p^{\uparrow}$	$e^{\uparrow}$-$p^{\uparrow}$, $d^{\uparrow}$, ^{3}He$^{\uparrow}$	p-$p^{\uparrow}$, $d^{\uparrow}$	p-$p^{\uparrow}$
Center-of-mass energy $\sqrt{s_{NN}}$, GeV	≤27 (p-p) ≤13.5 (d-d) ≤19 (p-d)	63, 200, 500	20-140 (ep)	115	115
Max. luminosity, 10^{32} cm^{-2} s^{-1}	~1 (p-p) ~0.1 (d-d)	2	1000	up to ~10 (p-p)	4.7
Physics run	>2025	running	>2030	>2025	>2025

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

CONCEPT OF THE SPD PHYSICS PROGRAM



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

Charmonia

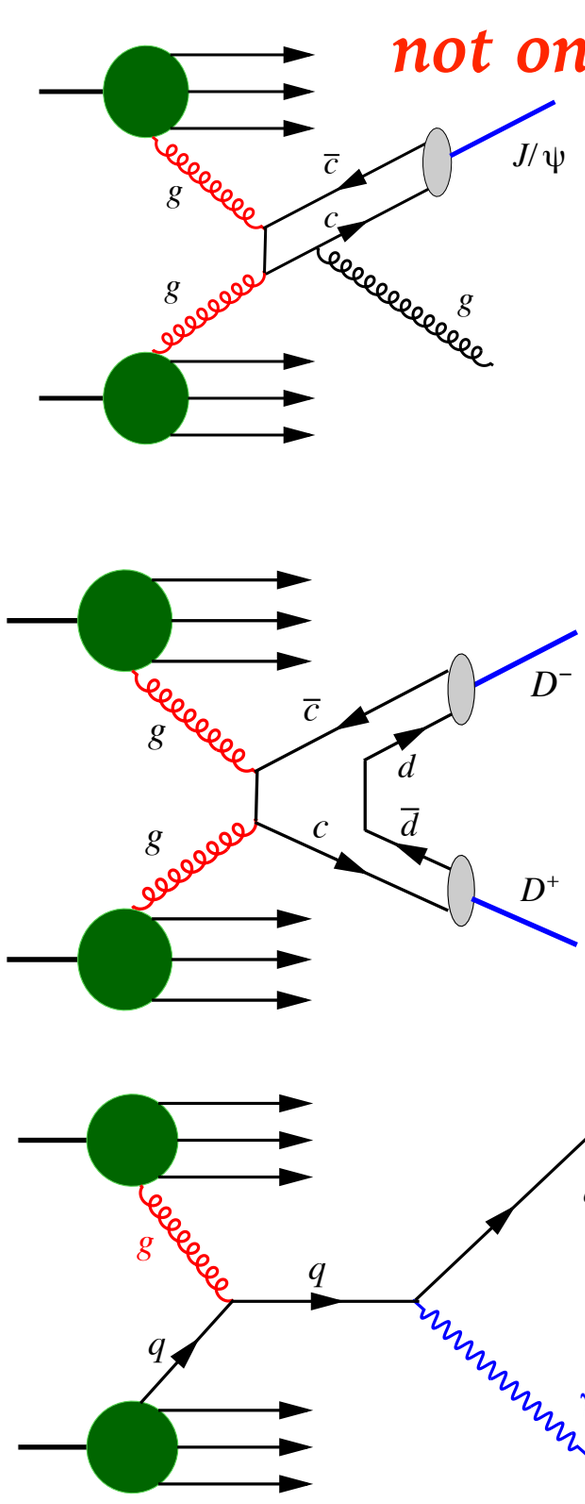
Prompt photons

Open charm

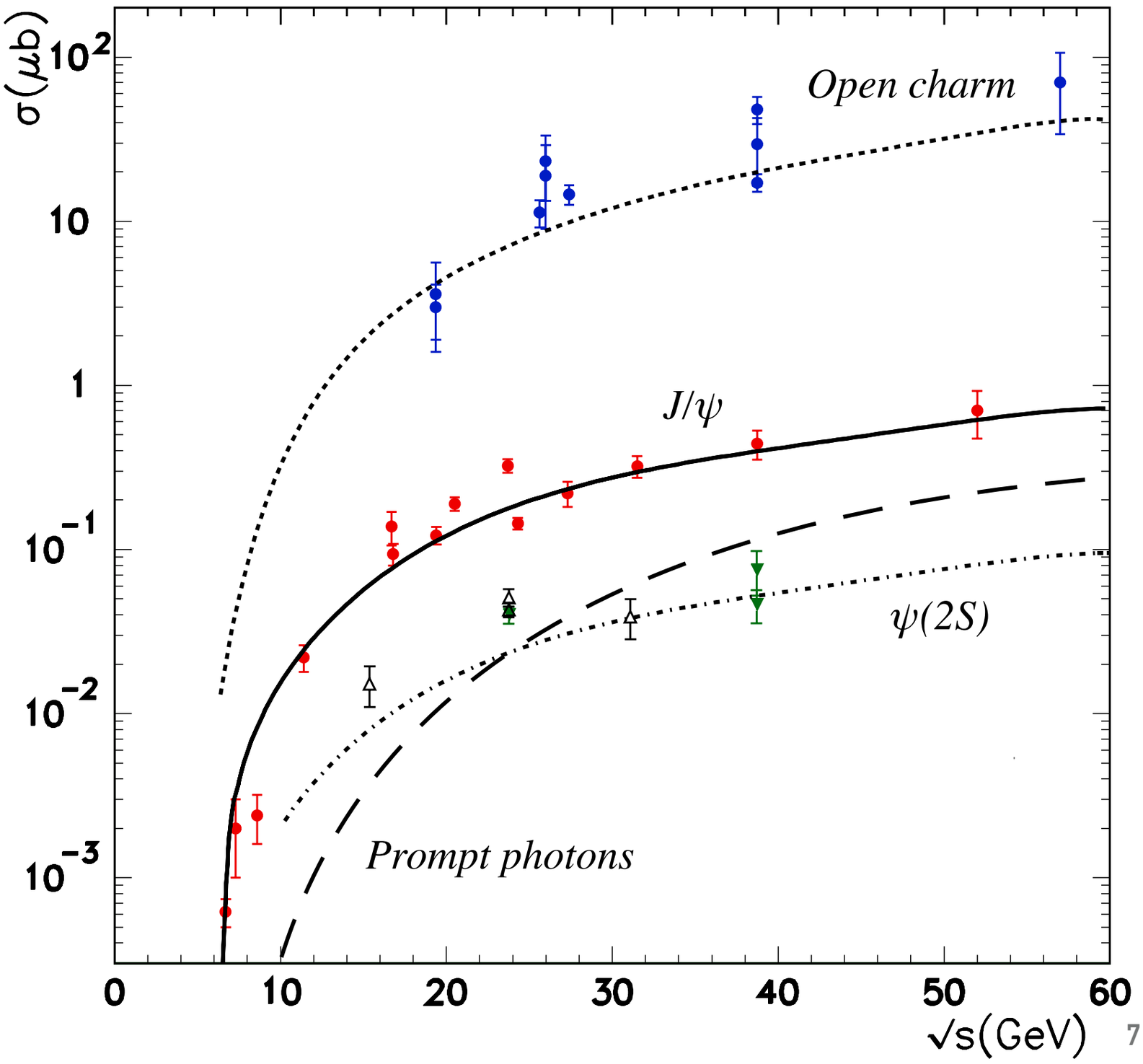
Other spin-related phenomena

Other physics

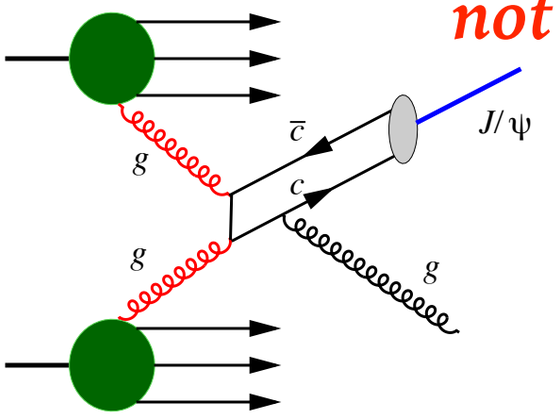
GLUON PROBES AT SPD



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



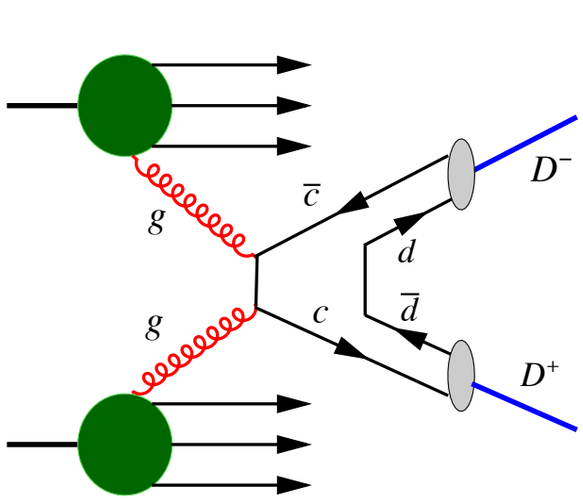
GLUON PROBES AT SPD



not only J/ψ!

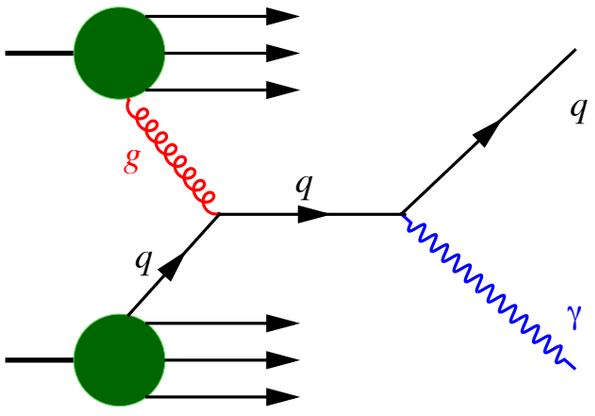
Sharp signal
Relatively large cross section

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



Largest cross section

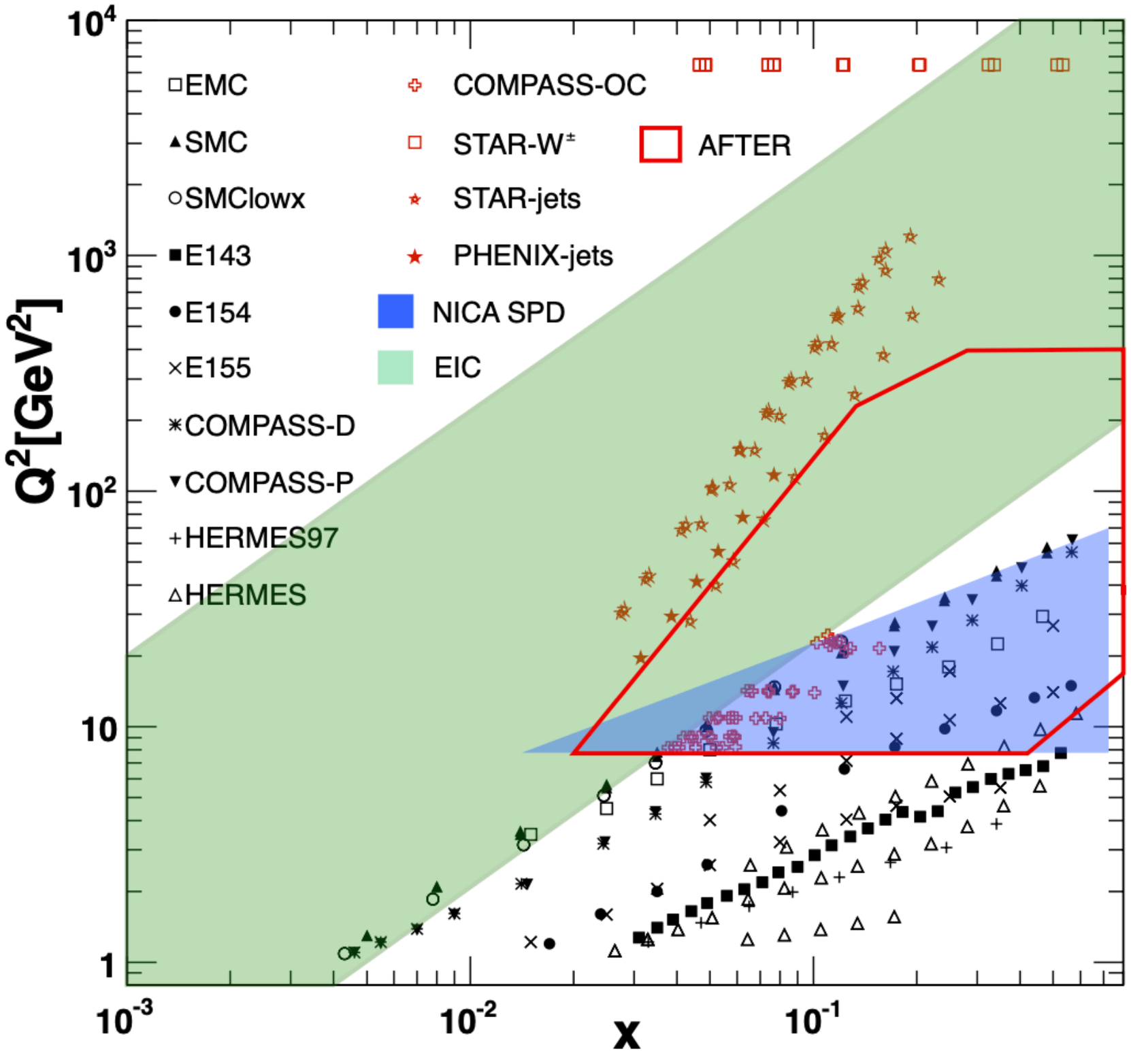
Challenging experimental requirements
Model-dependent fragmentation functions

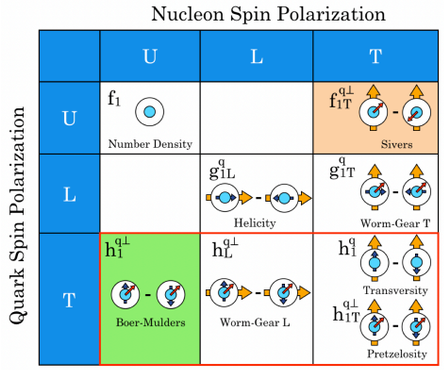


Almost no fragmentation

Strong background especially at low p_T

KINEMATIC RANGE





PARTONIC STRUCTURE OF PROTON

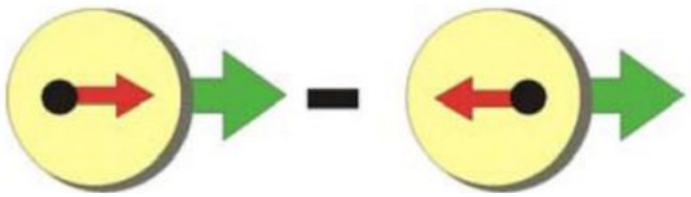
Prog.Part.Nucl.Phys. 119 (2021) 103858 arXiv:2011.15005

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

Unpolarized gluons in proton at high x:

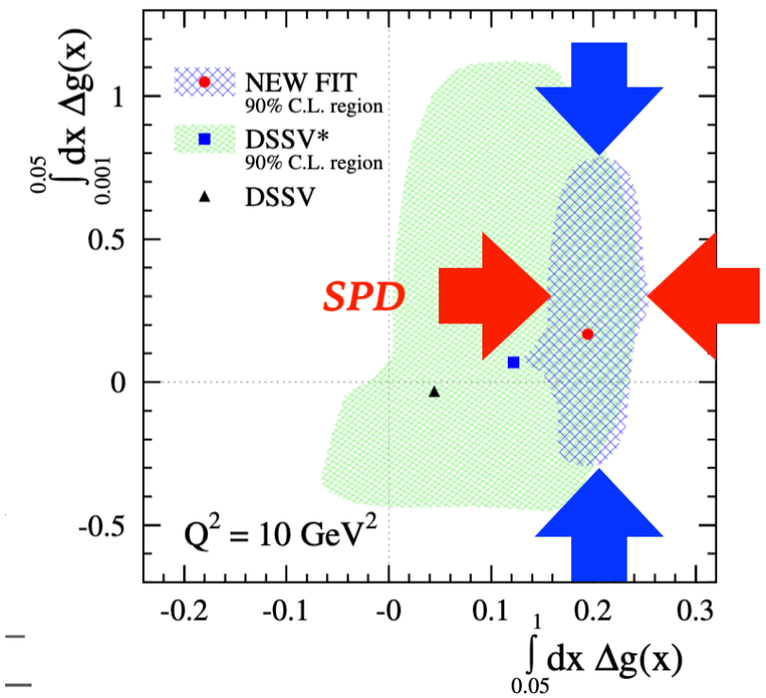
Spin crisis:

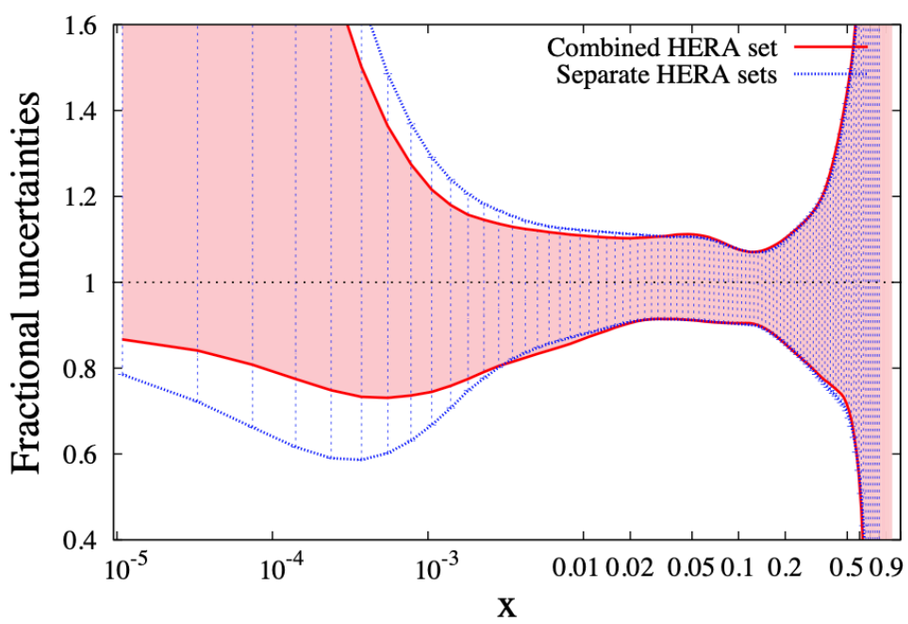
Gluon helicity



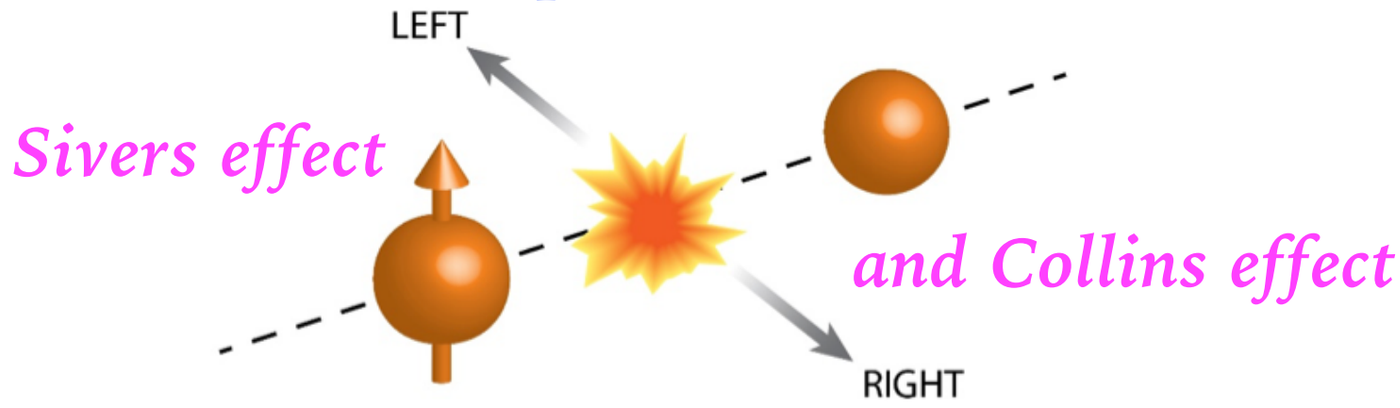
Phys.Rev.Lett. 113 (2014) 1, 012001

EIC





Gluon and quark TMD PDFs:



Spin-dependent fragmentation functions

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

. . . AND DEUTERON

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

Nonbaryonic content of deuteron:

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

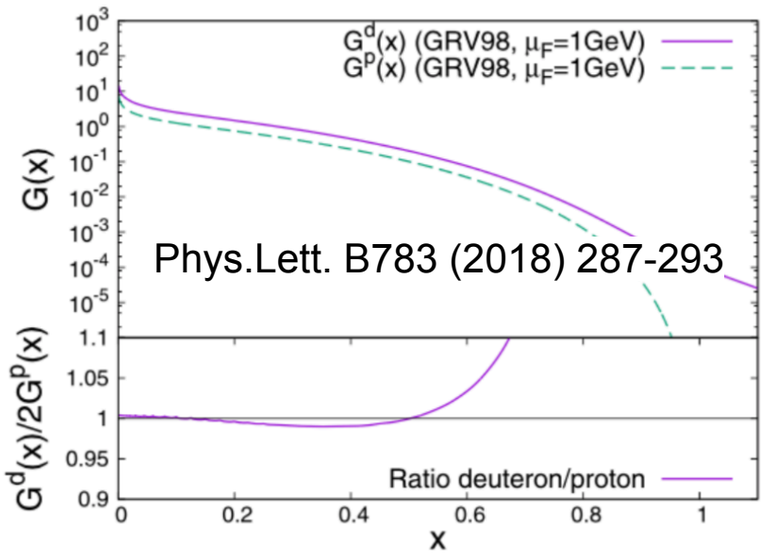
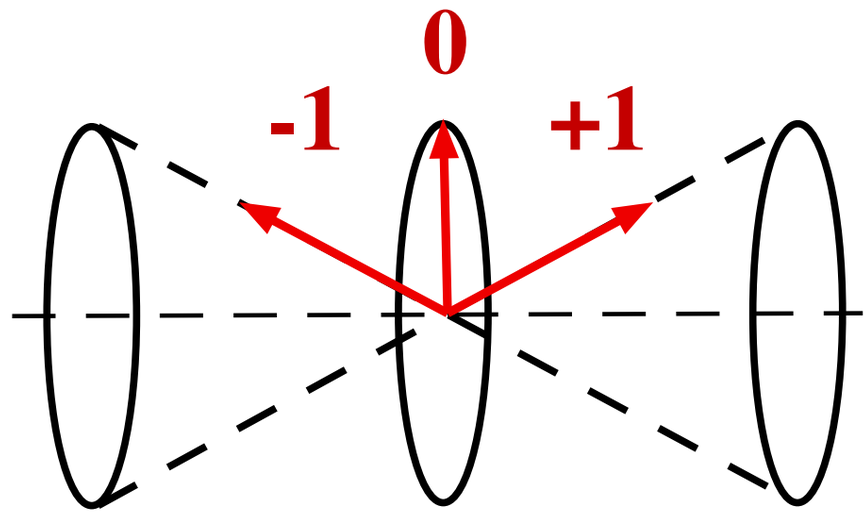


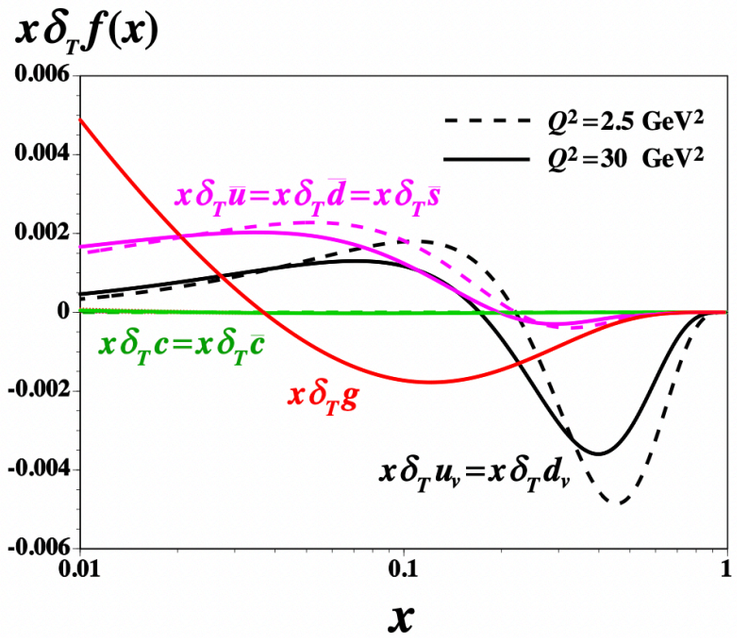
Fig. 6. Gluon PDF in the deuteron and in the nucleon.



Gluon transversity

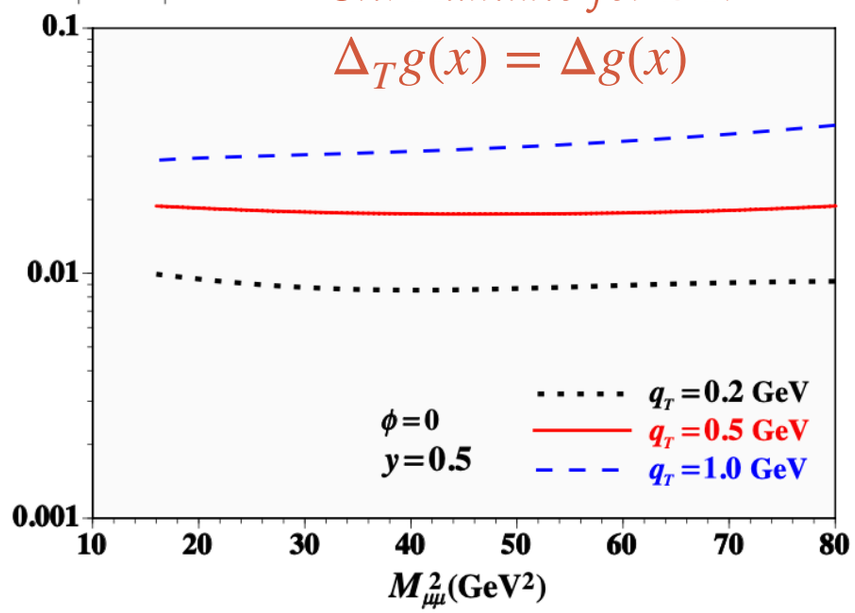
Tensor PDFs

Unpolarized gluons at high x:

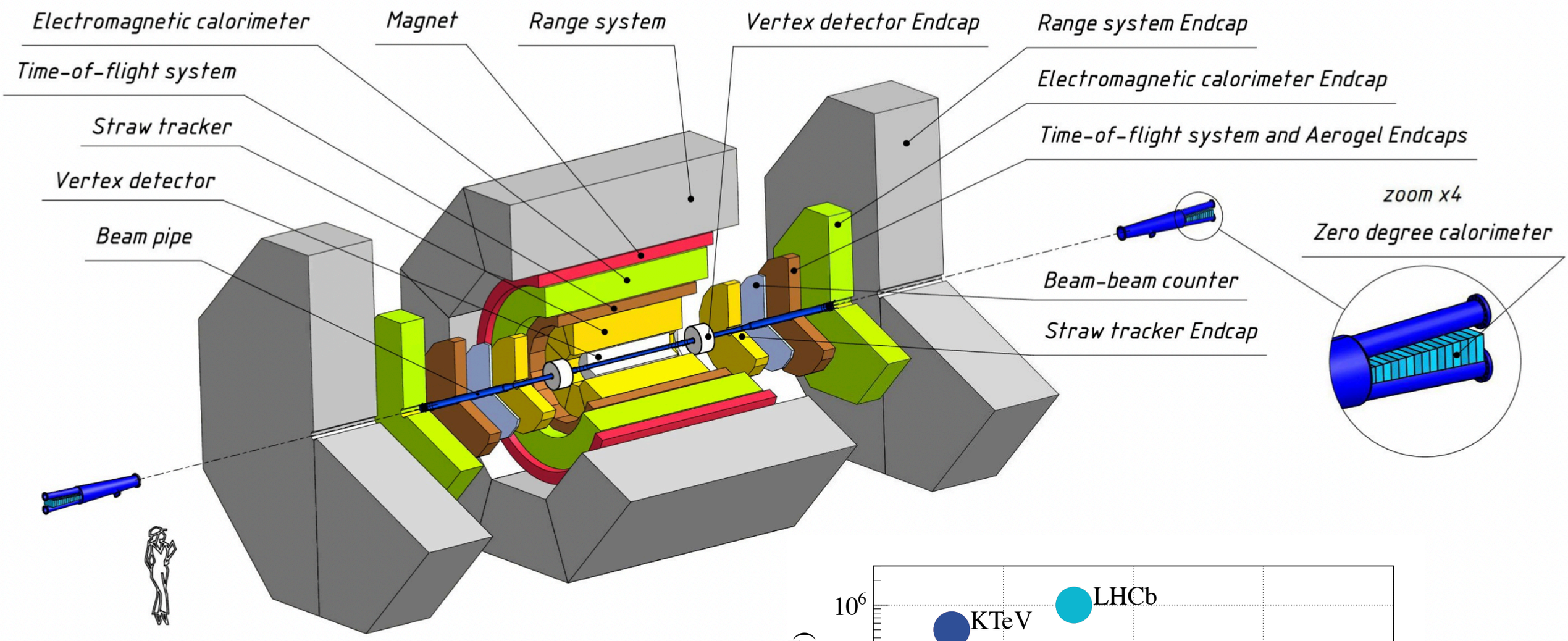


Sh. Kumano for DY:

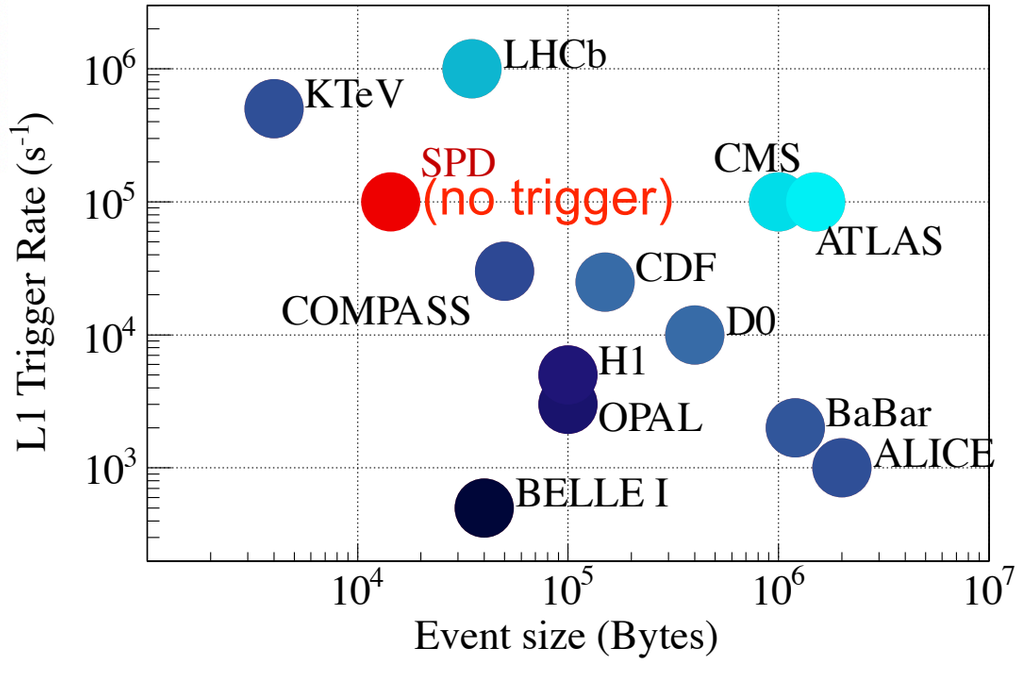
$$\Delta_T g(x) = \Delta g(x)$$



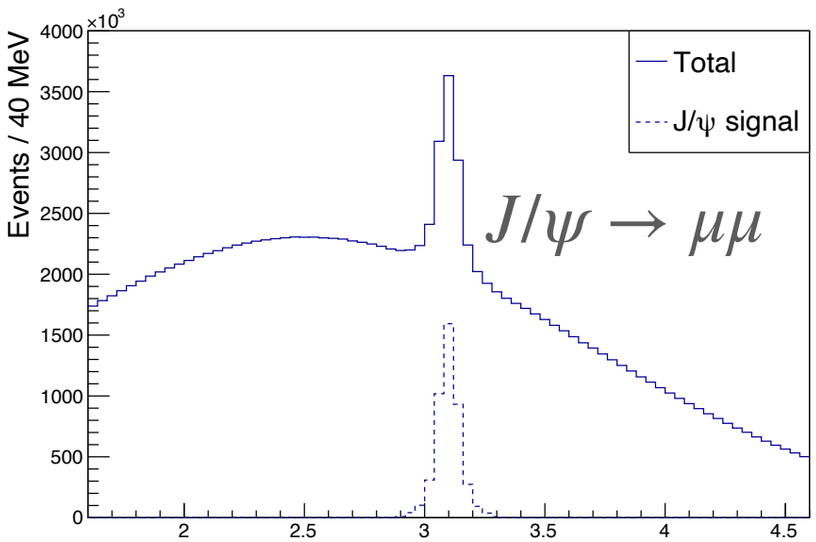
SPD DETECTOR

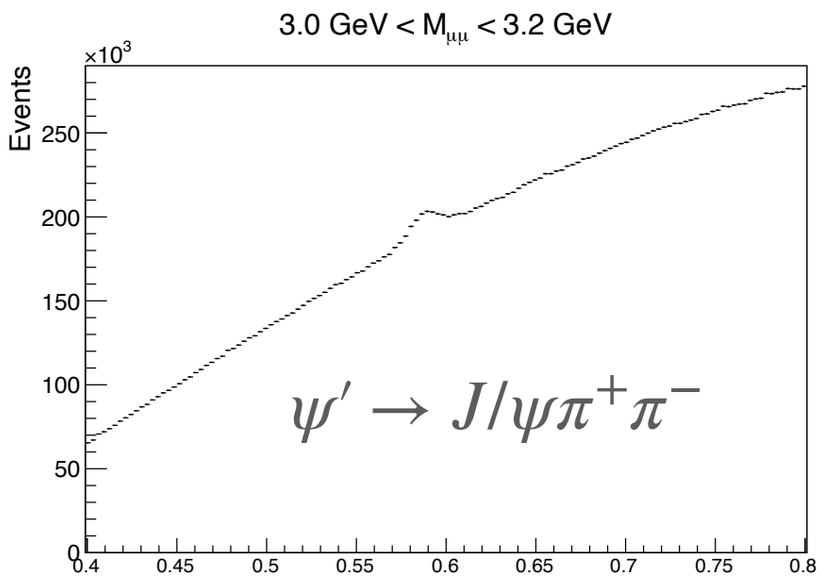


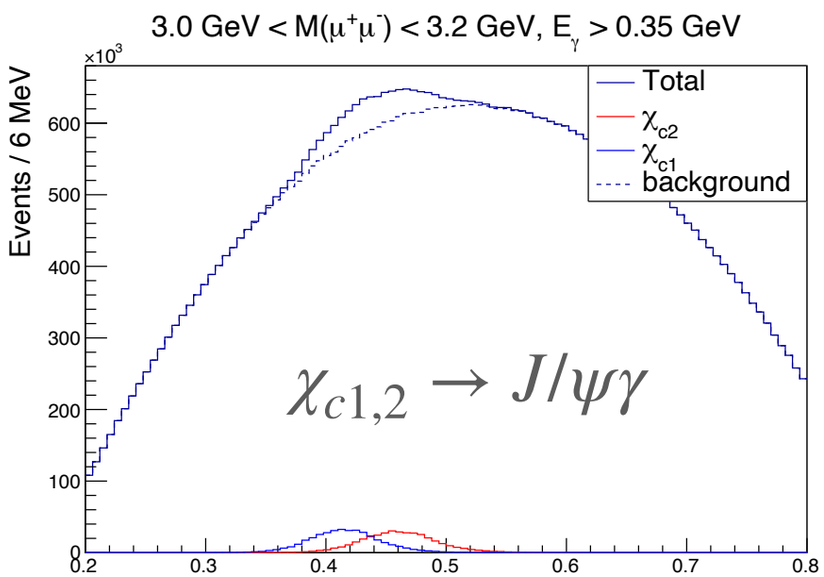
No hardware triggers to avoid possible bias!

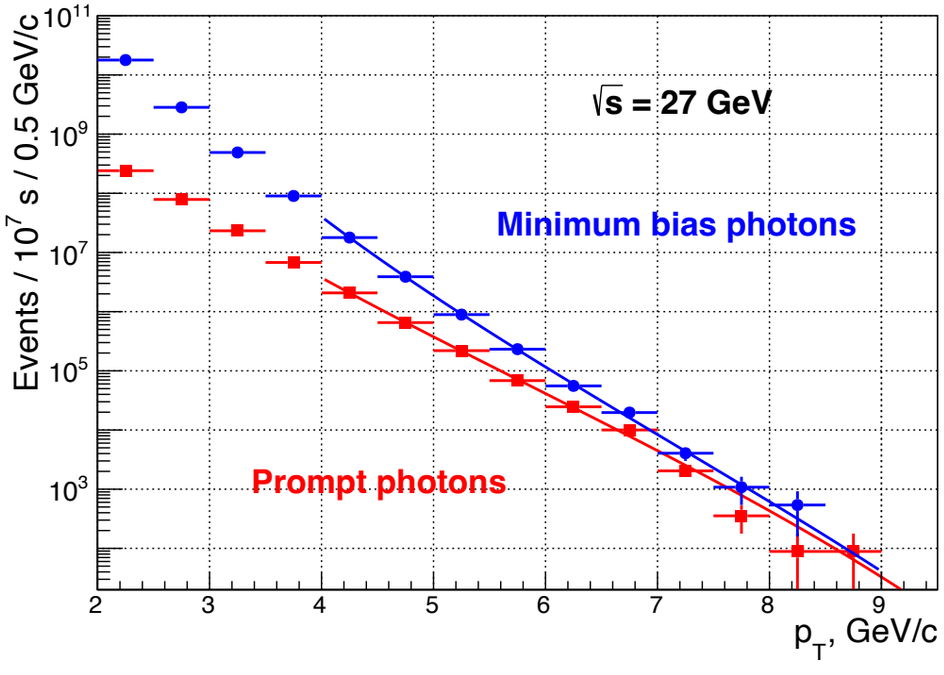


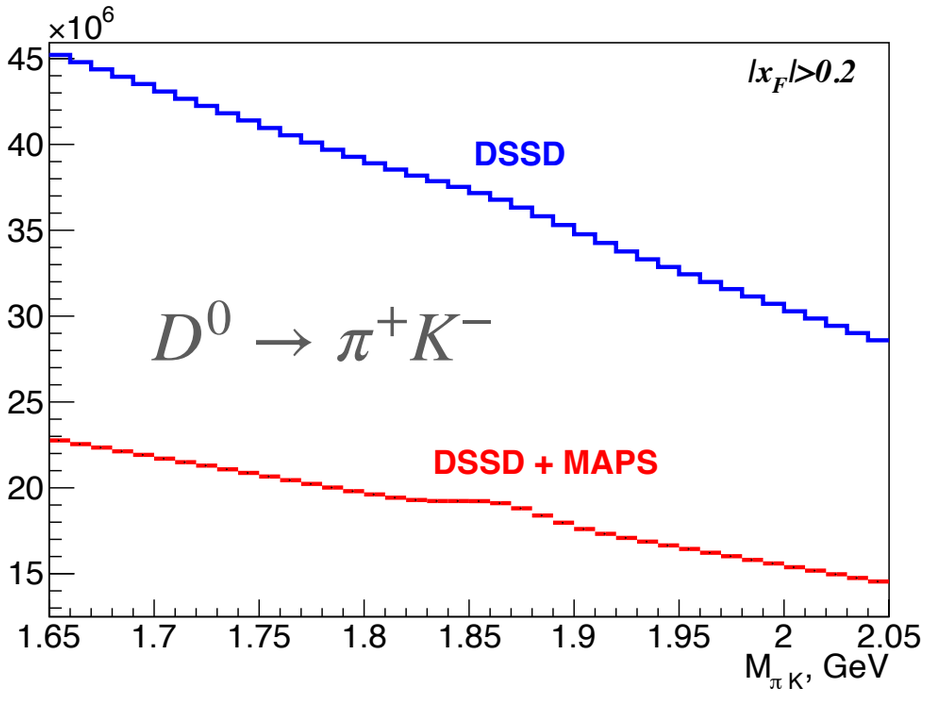
PHYSICS PERFORMANCE: GLUON PROBES (1 YEAR=10^7 S)



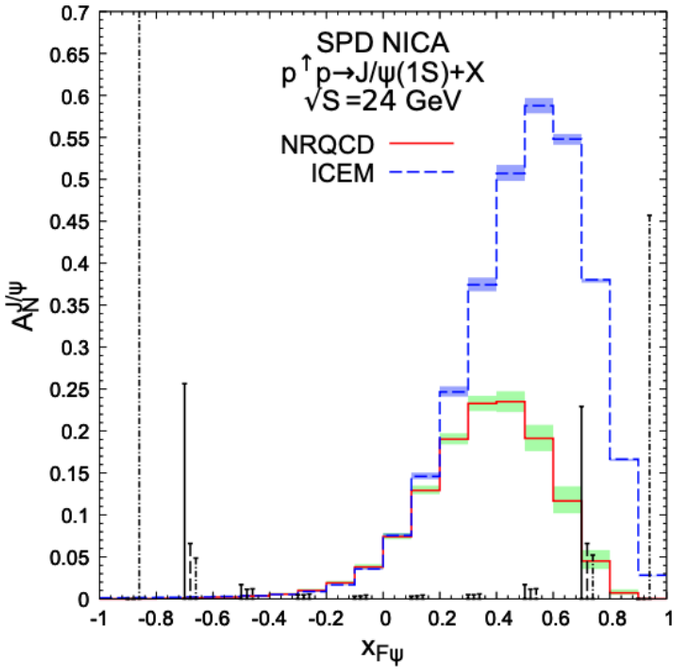




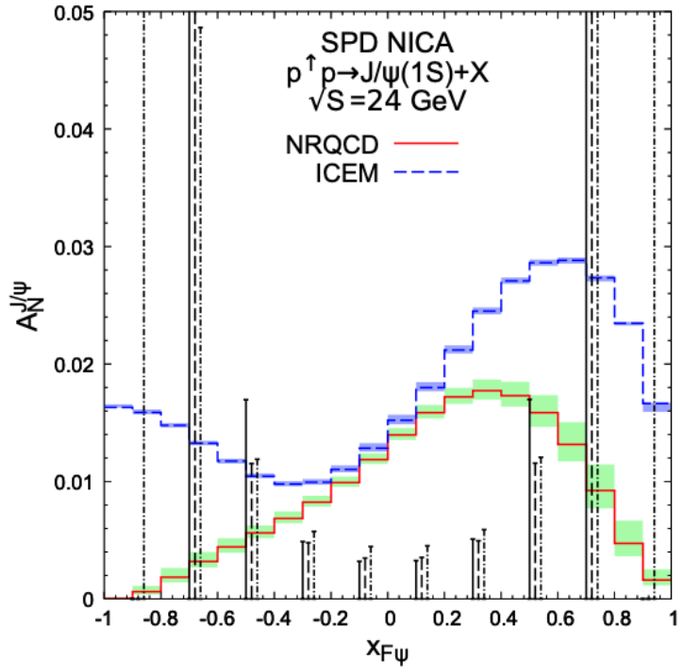


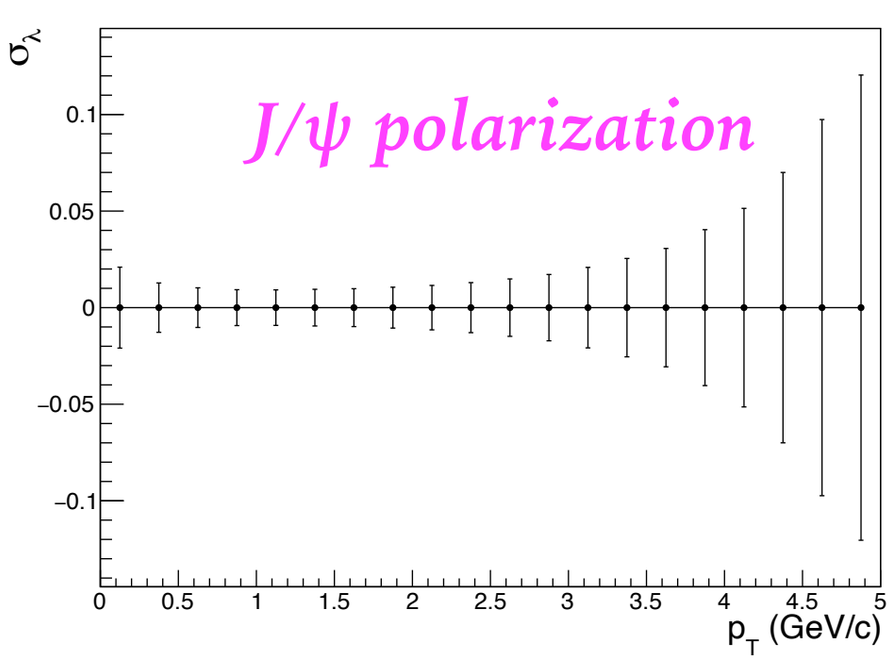


PHYSICS PERFORMANCE: ACCURACIES



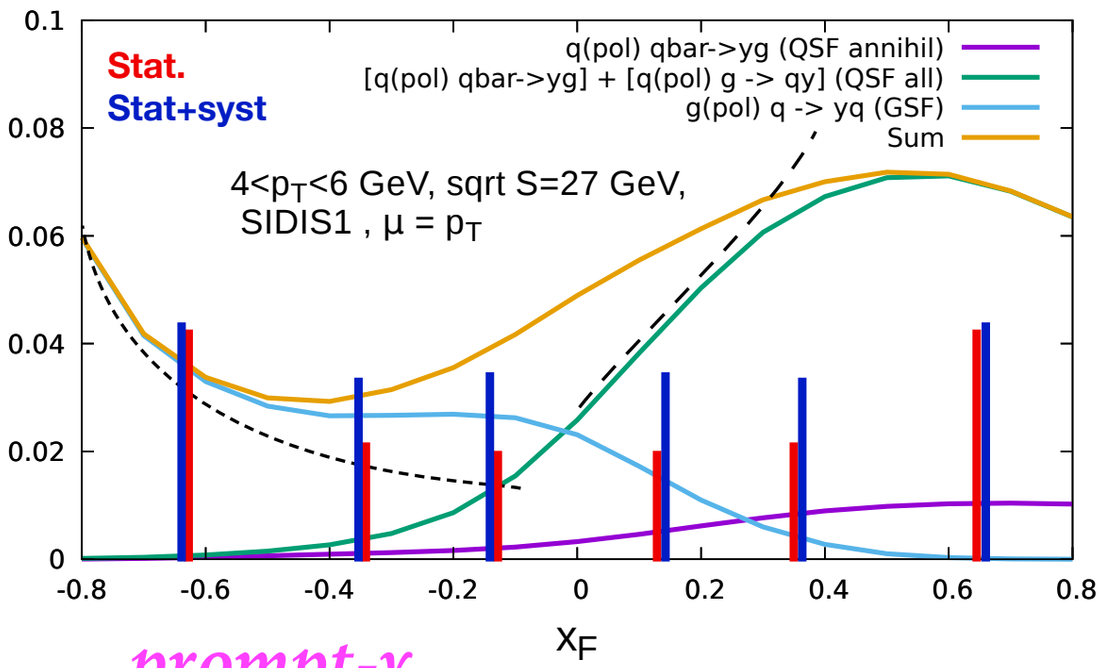
J/ψ



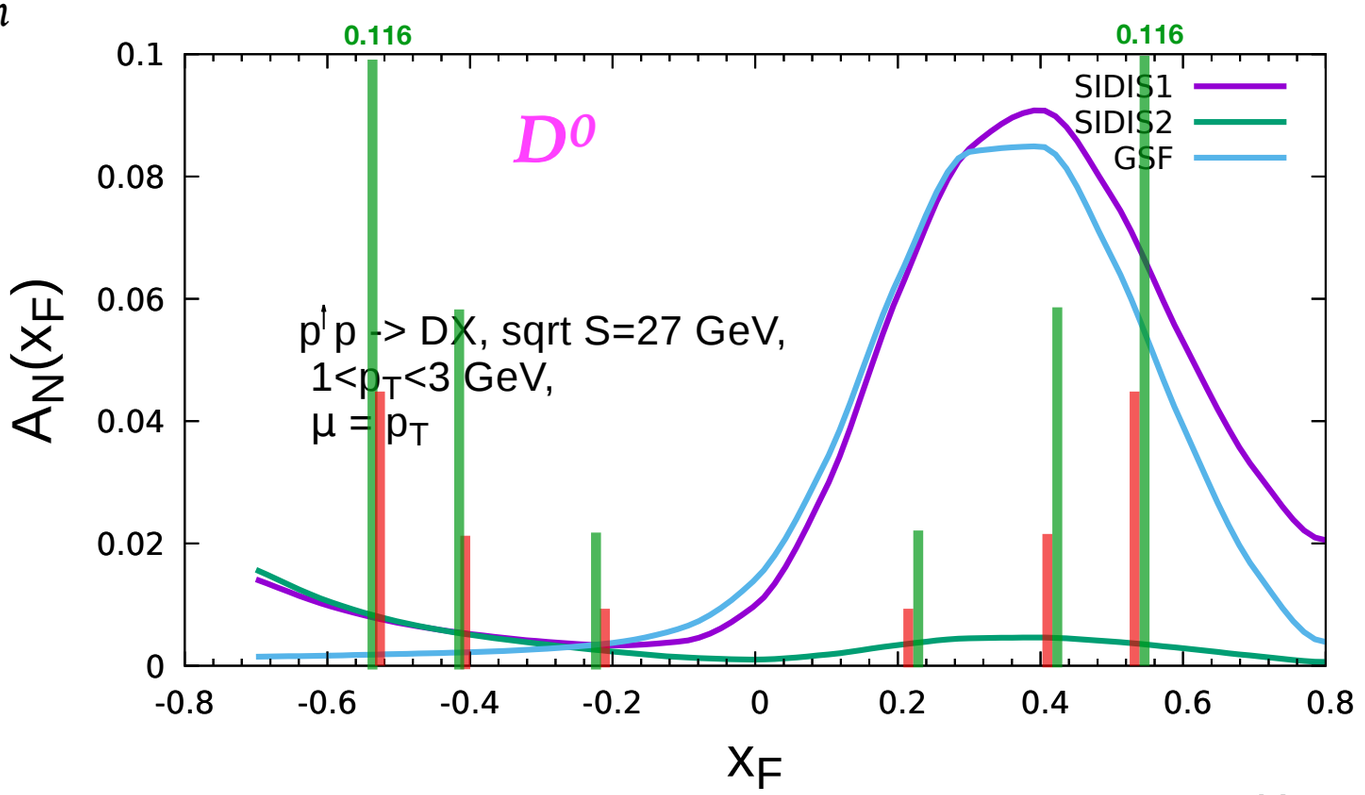


J/ψ polarization

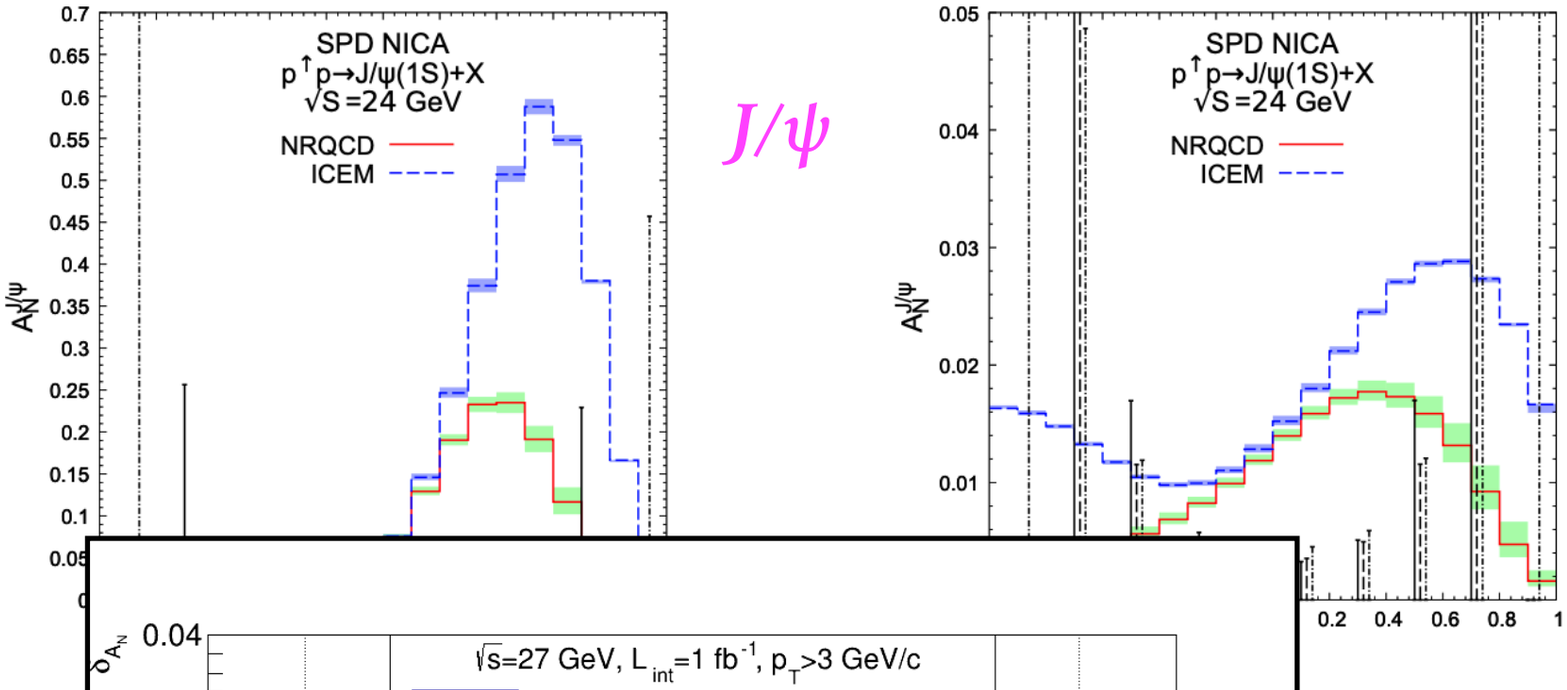
Different inputs for gluon Sivers function



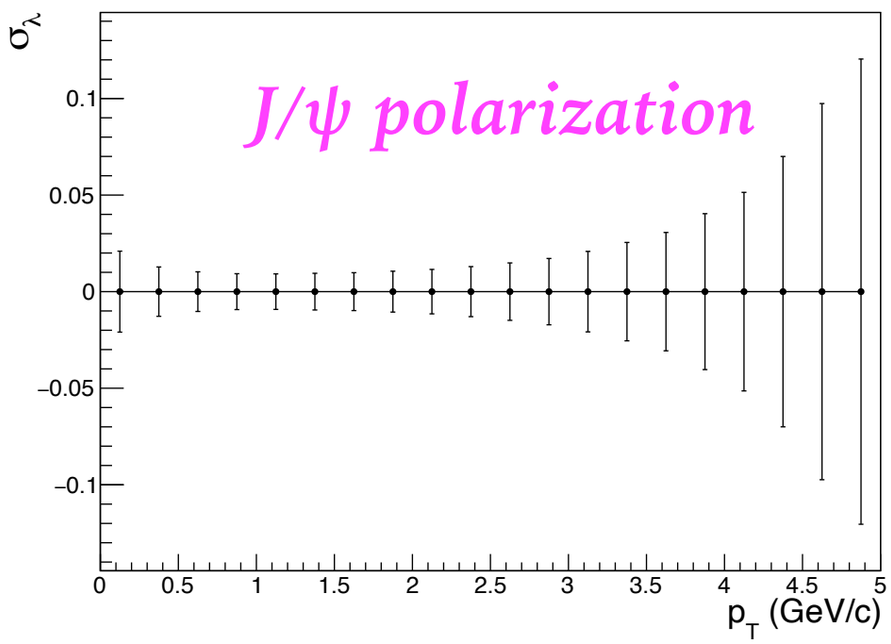
prompt-γ



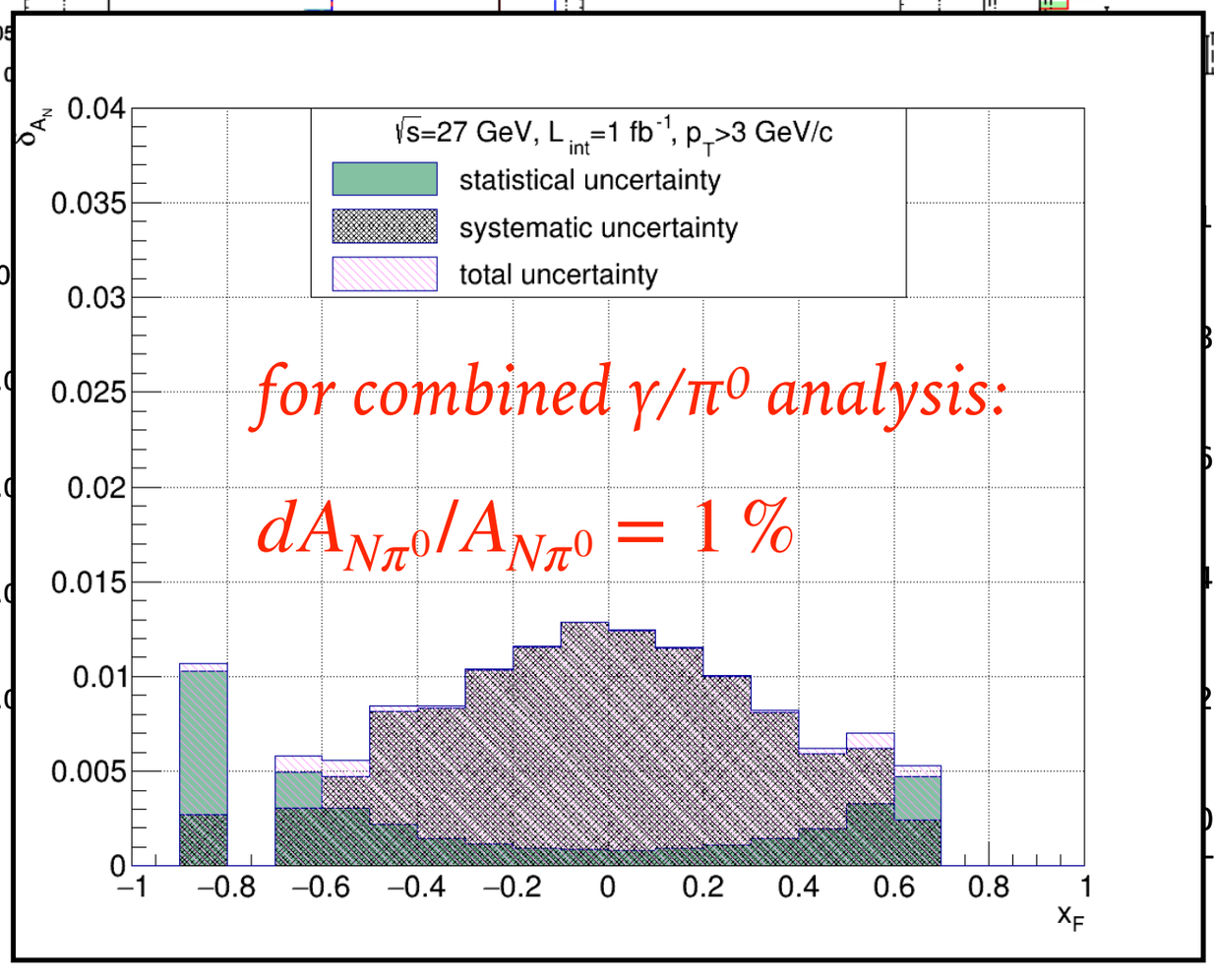
PHYSICS PERFORMANCE: ACCURACIES



J/ψ

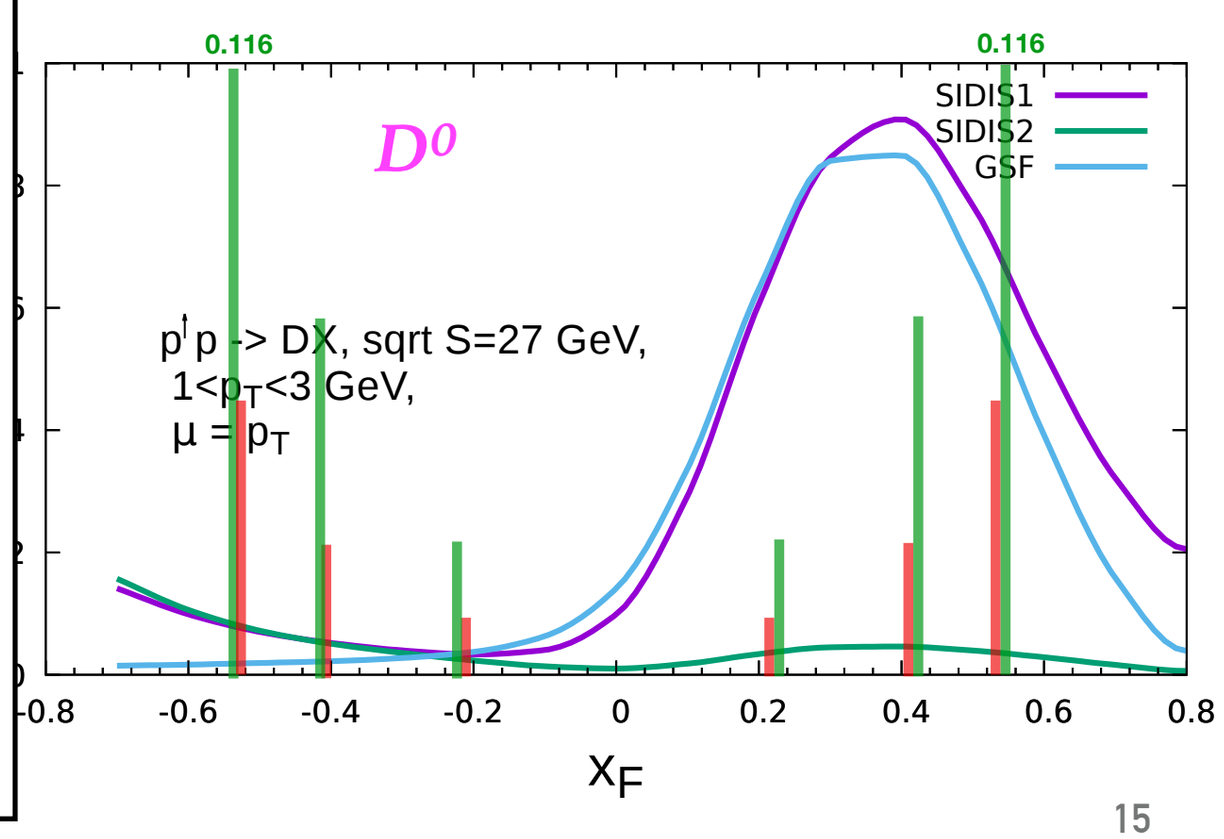


J/ψ polarization

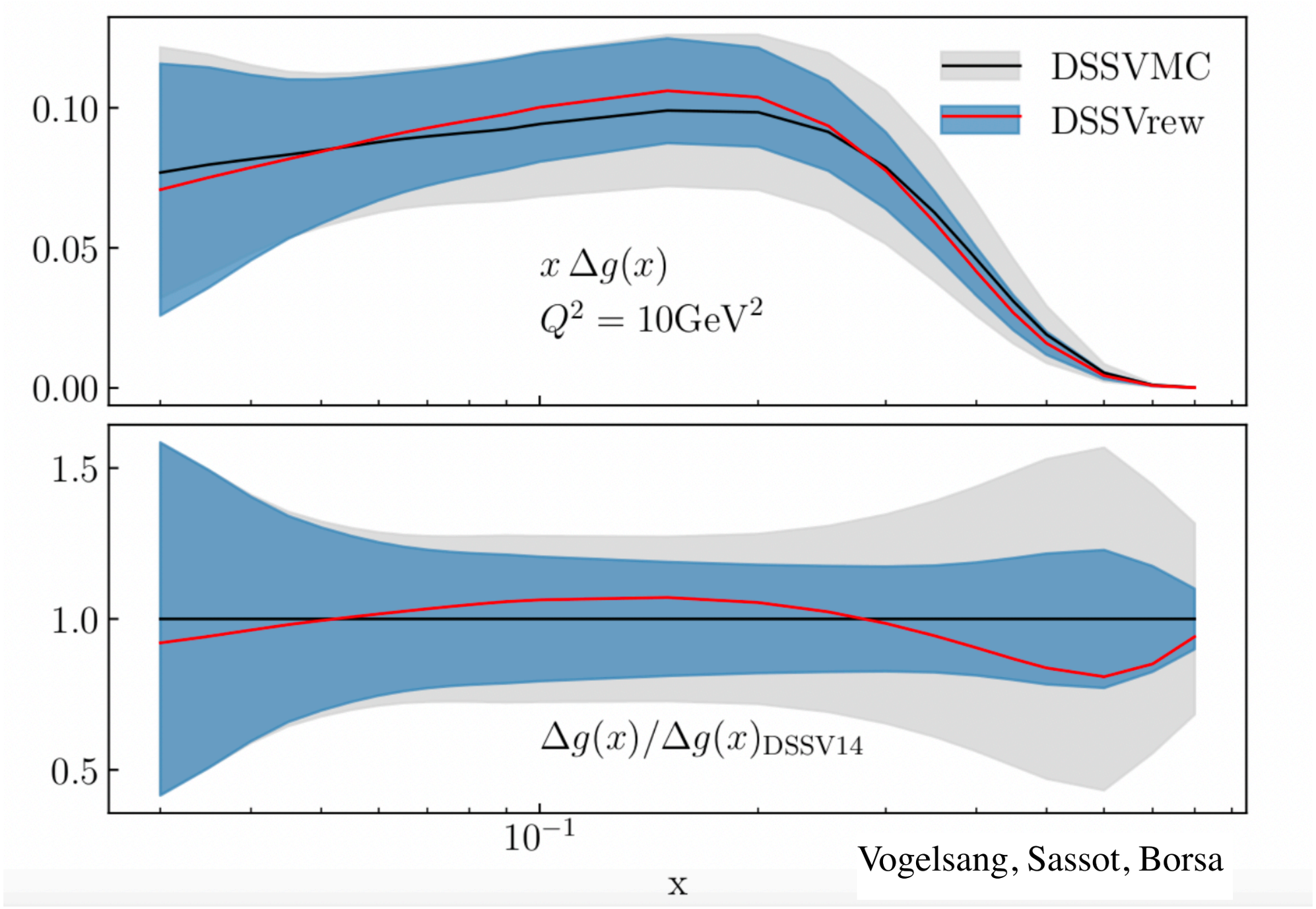


for combined γ/π^0 analysis:

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

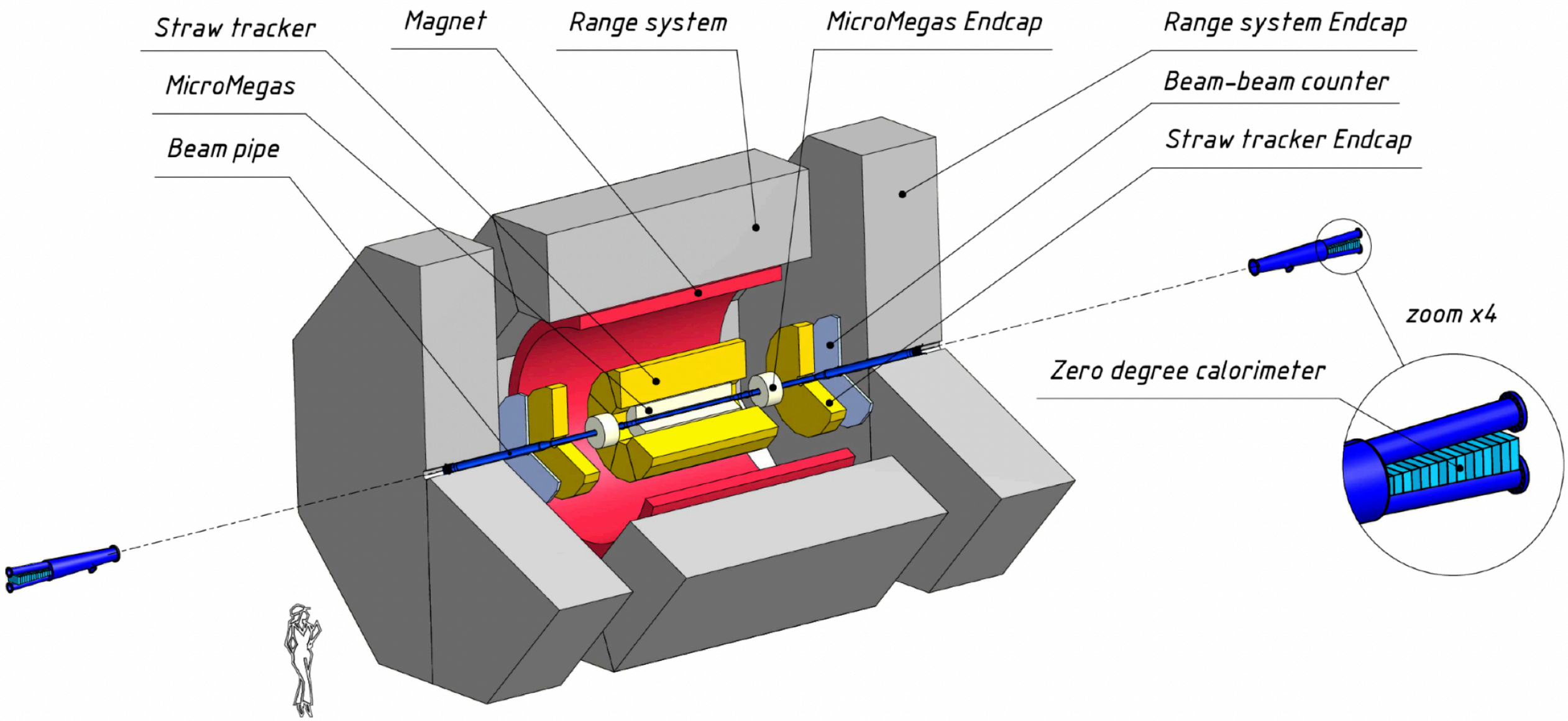


IMPACT OF SPD MEASUREMENTS TO THE WORLD DATA FOR Δg(x)



Vogelsang, Sassot, Borsa

SPD: PHASE-I



Running with reduced beam energy and luminosity

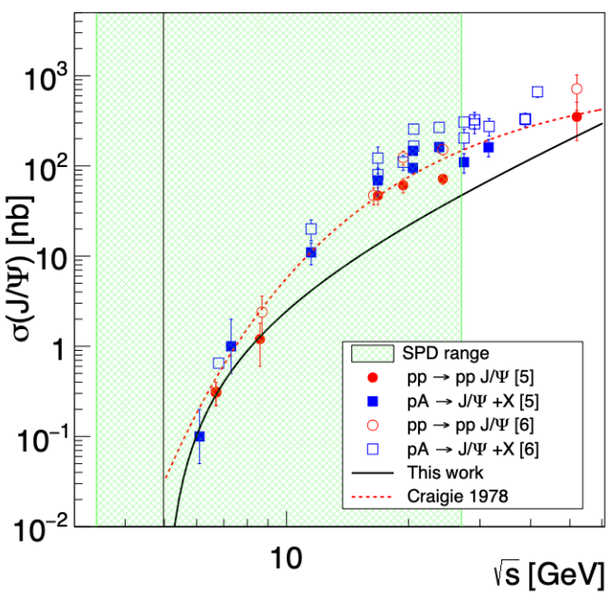
Physics of Particles and Nuclei v52, p1044–1119 (2021) arXiv:2102.08477

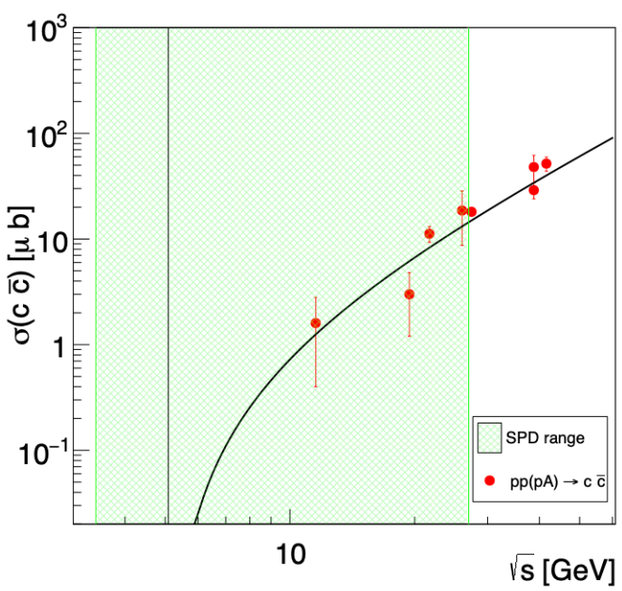
PHYSICS OF THE FIRST STAGE OF SPD RUNNING

Non-perturbative QCD — *Perturbative QCD*

$\sqrt{s}$

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





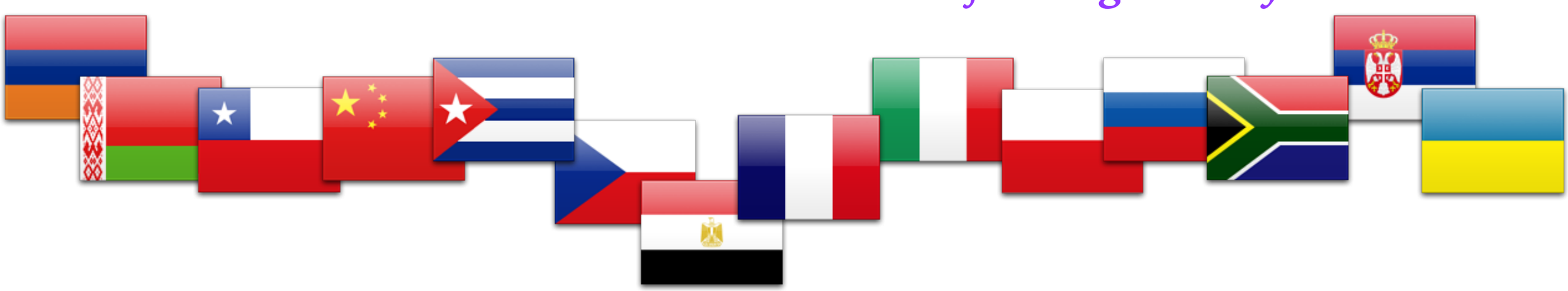
Reduced luminosity and beam energy.

- Auxiliary measurements for Dark Matter search in astrophysical experiemnts
- …

SPD INTERNATIONAL COLLABORATION

31 institutes from 14 countries, ~300 members

The SPD international collaboration is forming actively



SPD CDR was issued in the beginning of 2021: arXiv:2102.00442

*CDR was approved by the international **Detector Advisory Committee** and **the JINR Program Advisory Committee for Particle Physics***

First version of the SPD TDR will be presented in 2022

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, p-d 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, AFTER, LHC-Spin, 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 .

BACKUP

POLARIZED BEAMS AT **NICA**

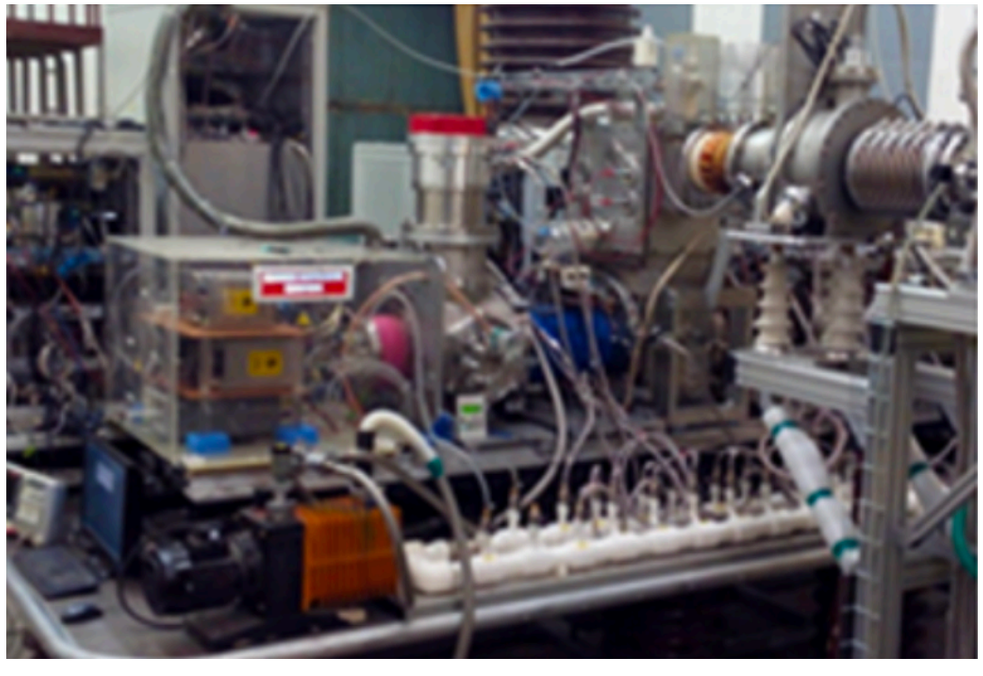
d↑- was accelerated in 1986 (Synchrophasotron) and 2002 (Nuclotron). It is quite simple procedure: there is just 1 depolarizing spin resonance at 5.6 GeV.

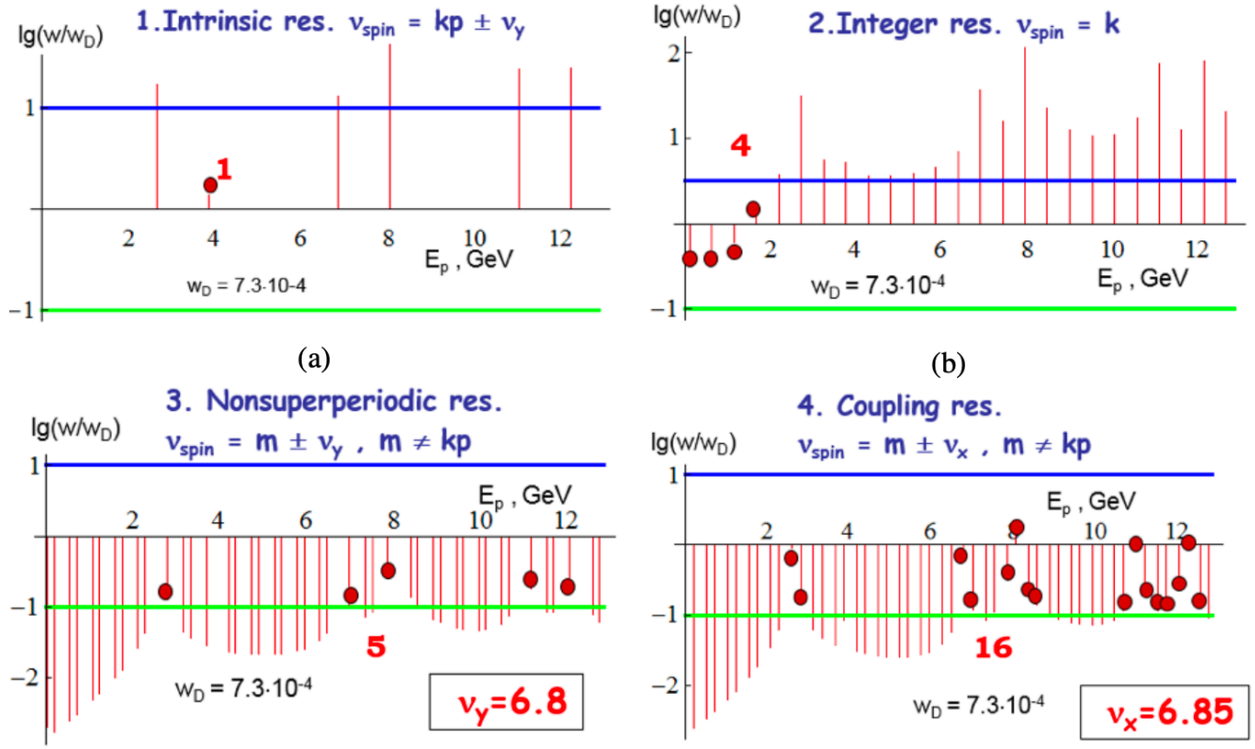
p↑- was first obtained only in 2017.

Source of Polarized Ions:

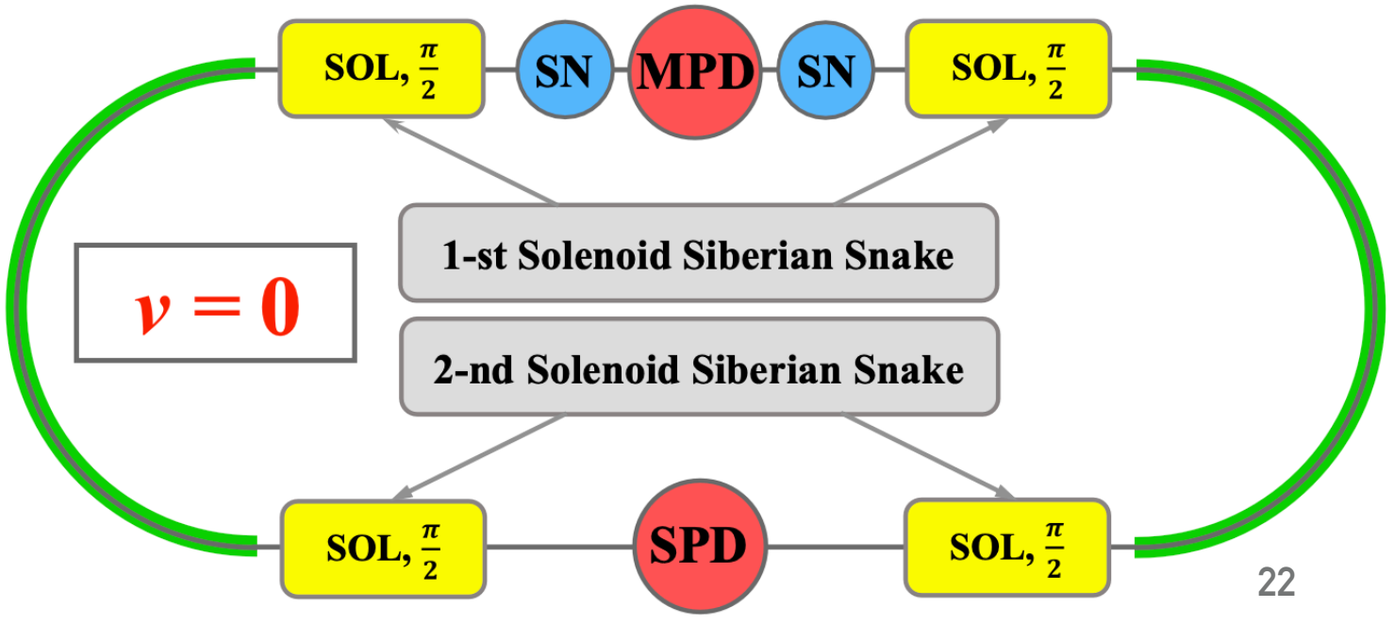
$$H^0 \uparrow + D^+ \rightarrow H^+ \uparrow + D^0$$

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

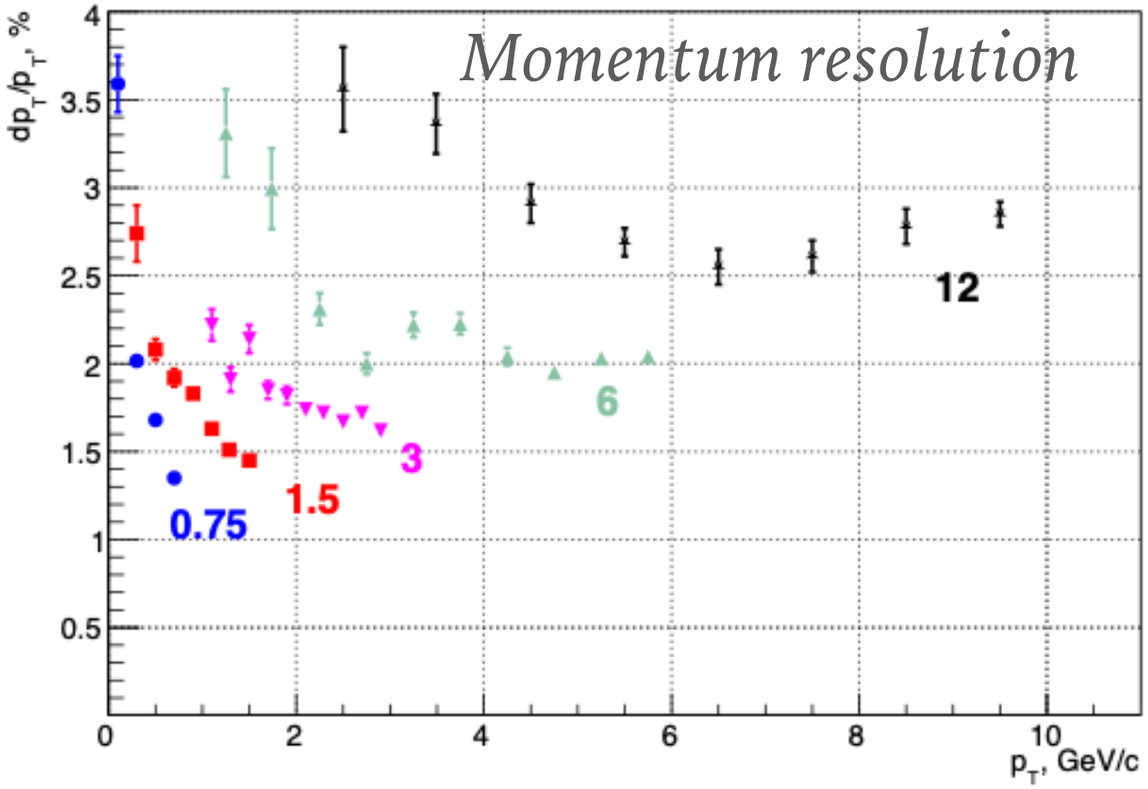




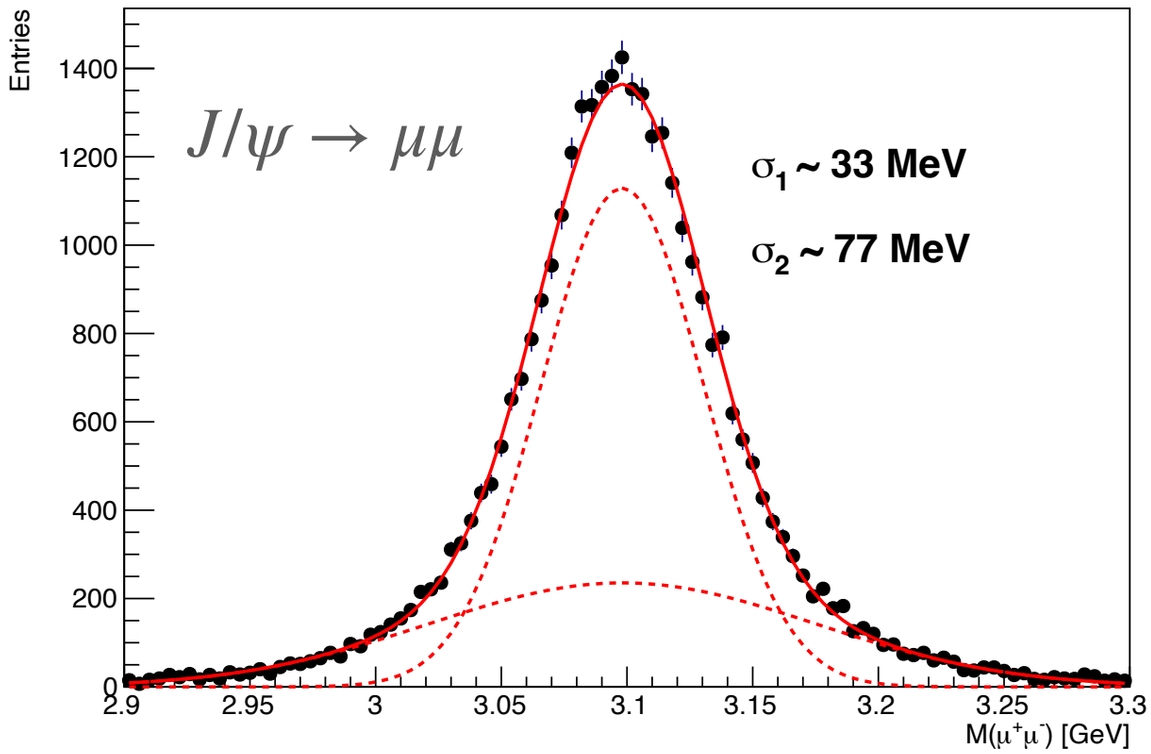
Spin Transparency mode for NICA ring



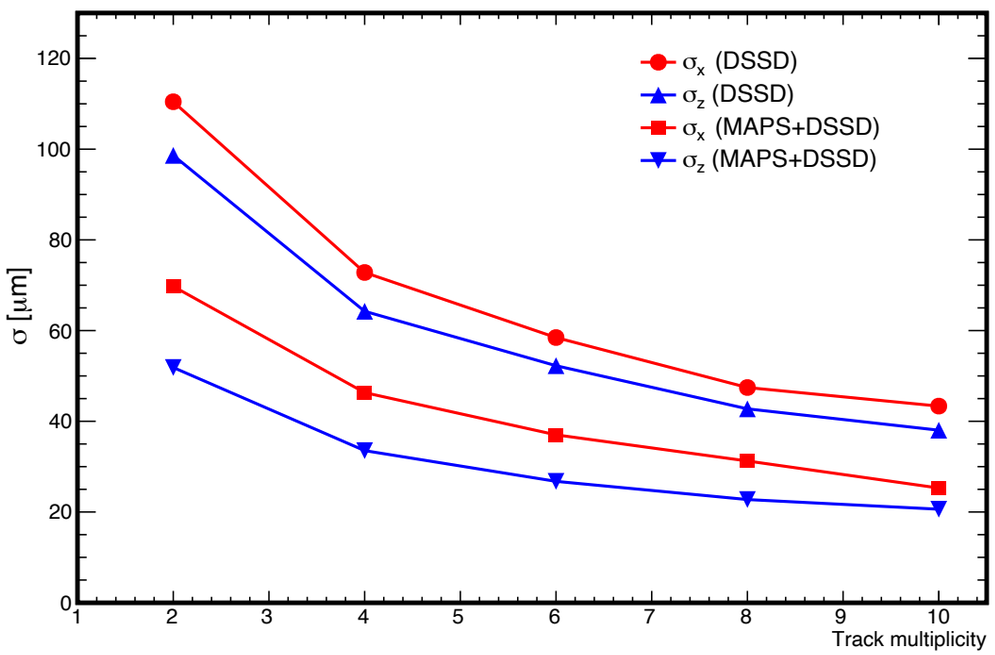
PHYSICS PERFORMANCE: TRACKING AND VERTEXING



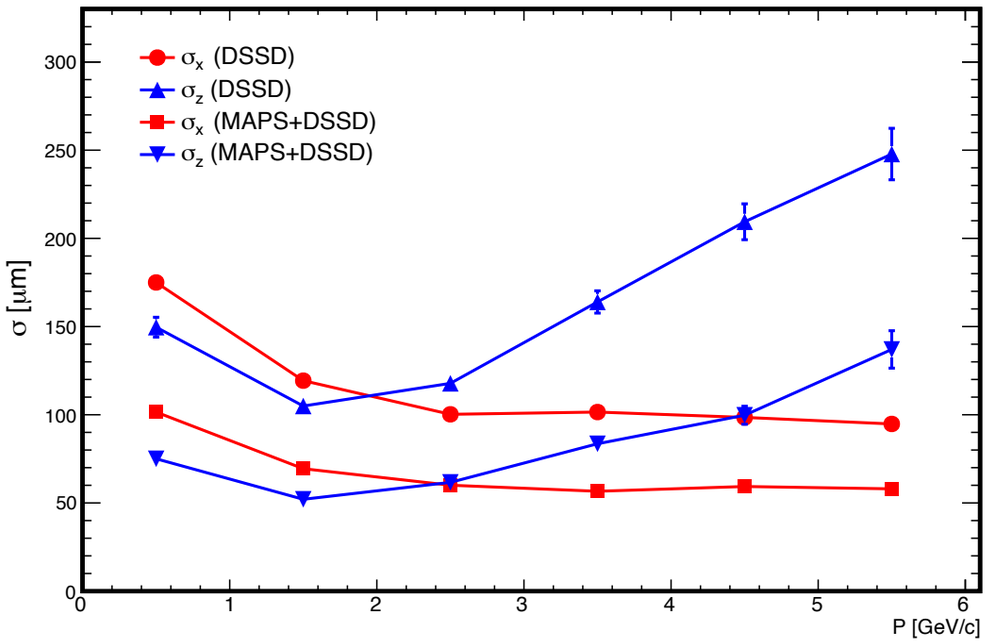
Dimuon mass spectrum fitted with the double Gaussian shape



Spatial resolution for primary vertices

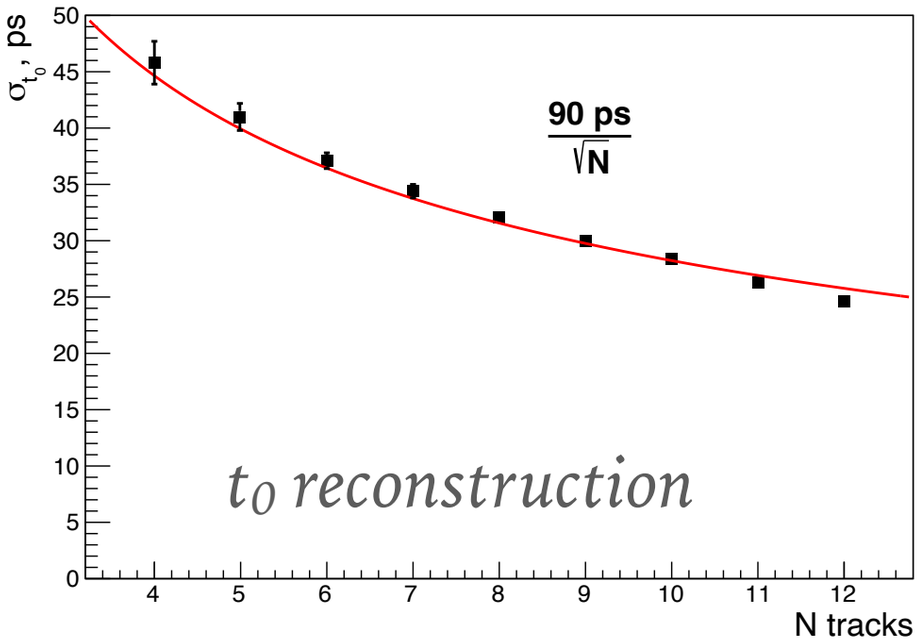


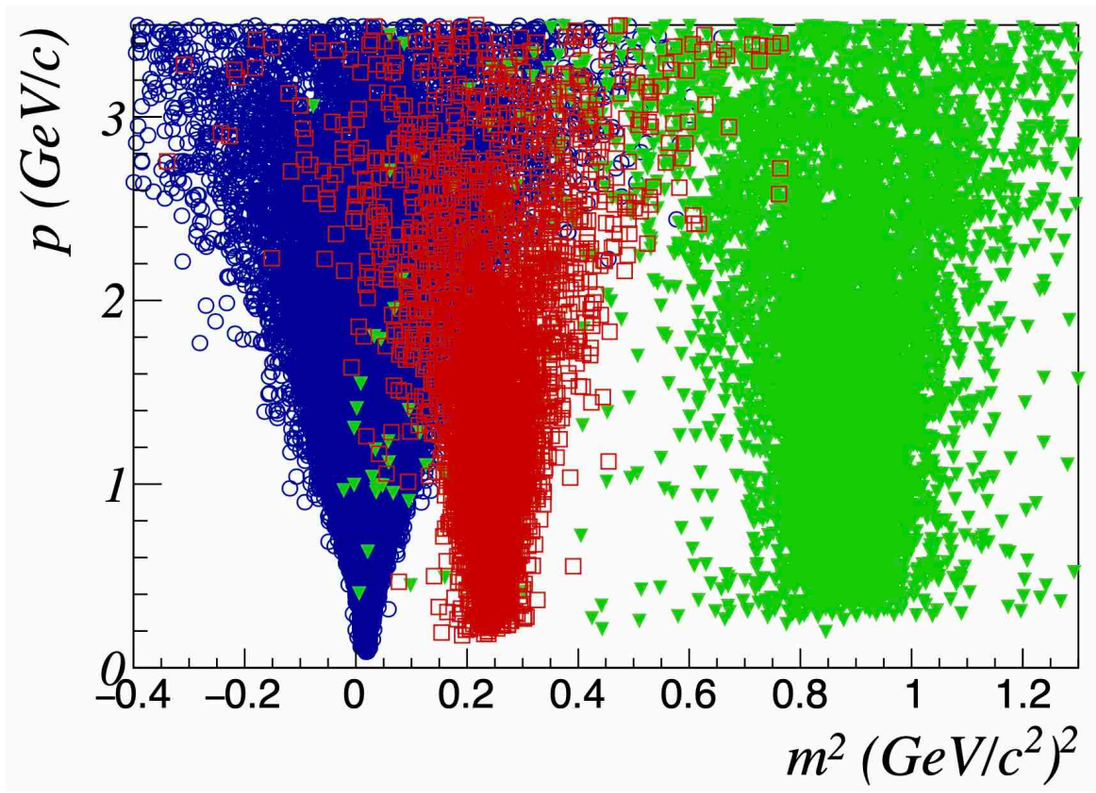
Spatial resolution for secondary D^0 decay vertices

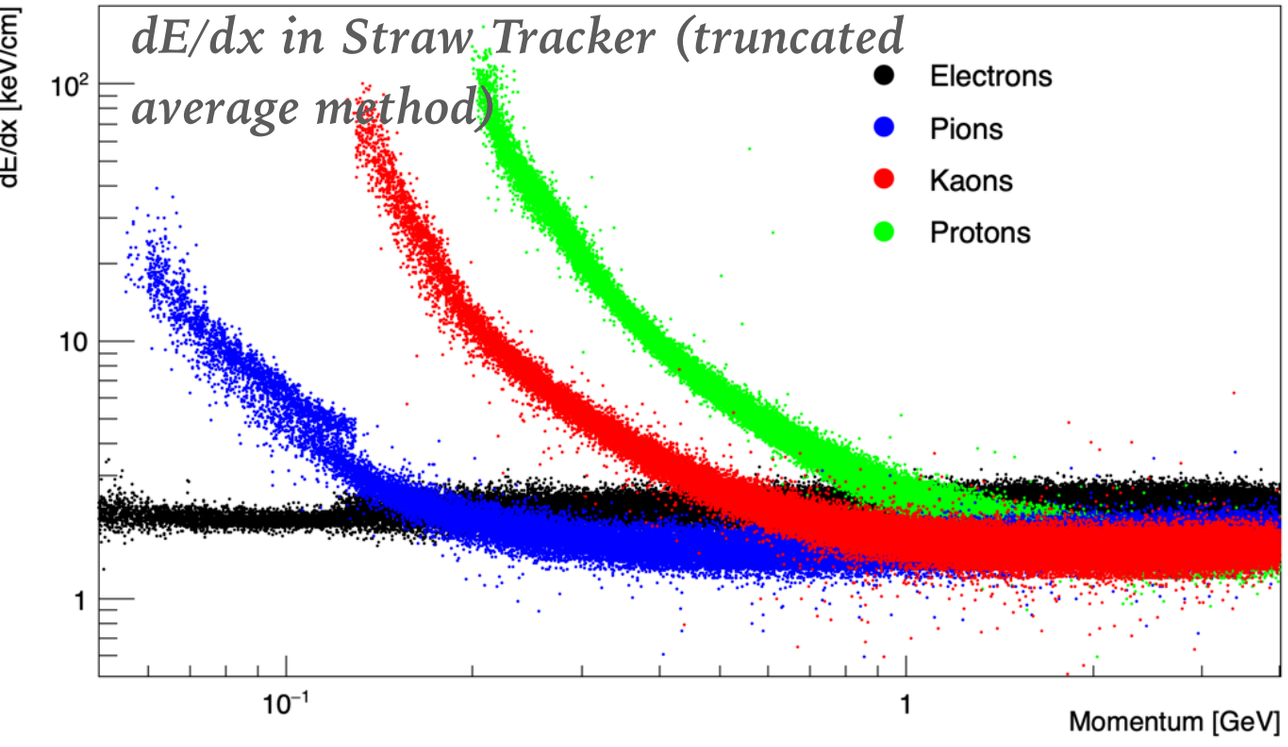


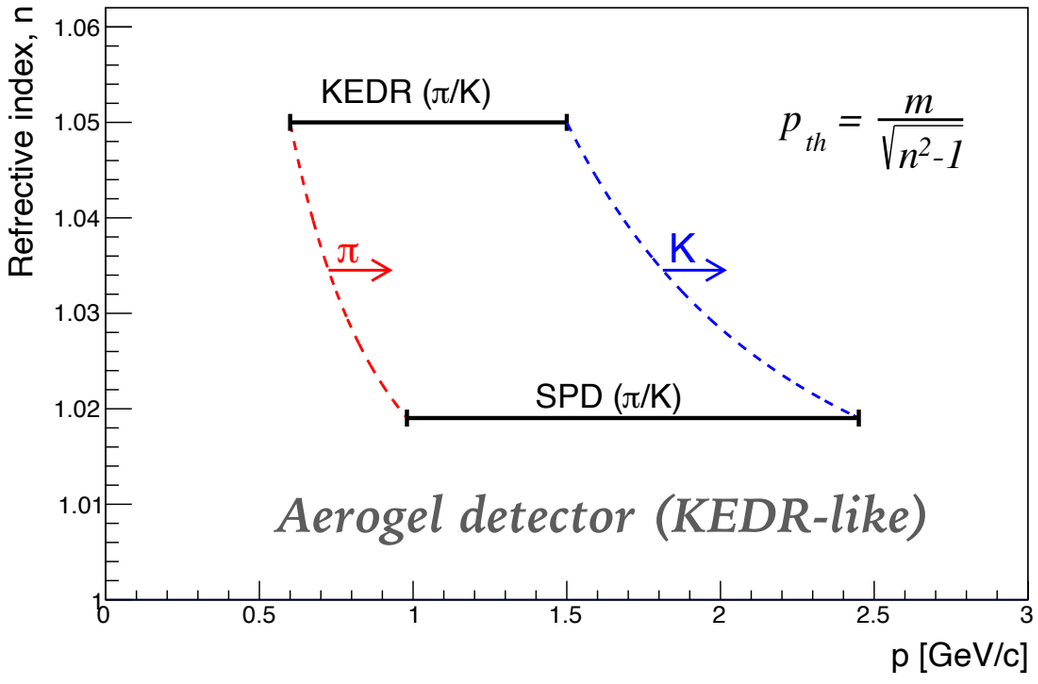
PHYSICS PERFORMANCE: PID

TOF (σ_T=70 ps)









PHYSICS PERFORMANCE: CALORIMETRY