

Report of the Physics Coordinator

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SPD Collaboration meeting
23-26 October 2023

Meetings:

- Physics & MC – monthly, **present results**
- The next Physics and MC meeting: **22.11.2023**
- Physics Weekly – **communication**, presenting **intermediate** results or status, **reporting problems**, asking for help, ...

People involved:

- Many involved people (Physics & MC – 30-45, Physics Weekly - 20-35)
- Smaller amount of actively contributing people
- Students supported by the SPD grants and JINR START program

SPD seminars:

- You can suggest topics for seminars

Communications

- email (SPD_MC mail list, private emails)
- **please, do not hesitate to communicate your problems via the mail list!**

Possible Studies at the First Stage of the NICA Collider Operation with Polarized and Unpolarized Proton and Deuteron Beams

V. V. Abramov^a, A. Aleshko^b, V. A. Baskov^c, E. Boos^b, V. Bunichev^b, O. D. Dalkarov^c, R. El-Kholy^d, A. Galoyan^e, A. V. Guskov^f, V. T. Kim^{g,h}, E. Kokoulina^{c,i}, I. A. Koop^{k,l,m}, B. F. Kostenko^m, A. D. Kovalenko^{n,†}, V. P. Ladygin^e, A. B. Larionov^{o,n}, A. I. L'vov^c, A. I. Milstein^{h,k}, V. A. Nikitin^e, N. N. Nikolaev^{p,z}, A. S. Popov^l, V. V. Polyanskiy^c, J.-M. Richard^q, S. G. Salmikov^l, A. A. Shavrin^r, P. Yu. Shatunov^{h,k}, Yu. M. Shatunov^{h,k}, O. V. Selyugin^q, M. Strikman^r, E. Tomasi-Gustafsson^r, V. V. Uzhinsky^m, Yu. N. Uzikov^{f,w,v,*}, Qi

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^b Skobeltsyn Institute of Nuclear Physics

^c Lebedev Physical Institute

^d Astronomy Department, Faculty of Science

^e Veksler and Baldin Laboratory of High Energy Physics, Moscow

^f Dzhelpev Laboratory of Nuclear Problems, Joint Institute for Nuclear Research

^g Petersburg Nuclear Physics Institute

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ⁱ Sukhoi State Technical University

^j Budker Institute of Nuclear Physics

- Also quark-instanton scattering (M.G. Ryskin talk at SPD seminar)
- Search for exotic states in central production (A. Sarantsev talk at the last CM)
- **Study of sum rules for TMDs** (see talk by Valery Lyubovitskij)
- **Nuclear physics tasks for light to moderate nuclei** (see talk by Grigory Nigmatkulov): spectra, yields, polarization phenomena, and hypernuclei production



ELSEVIER

Progress in Particle and Nuclear Physics

Volume 119, July 2021, 103858



Review

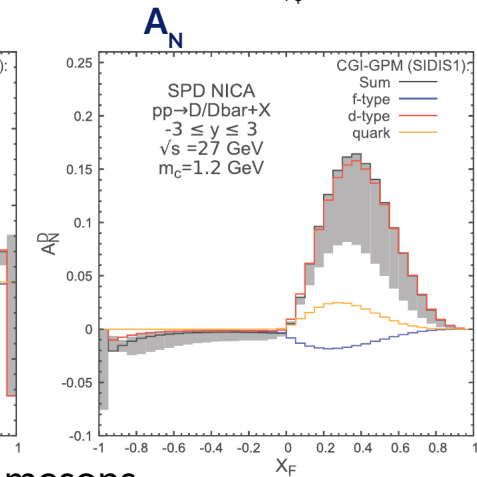
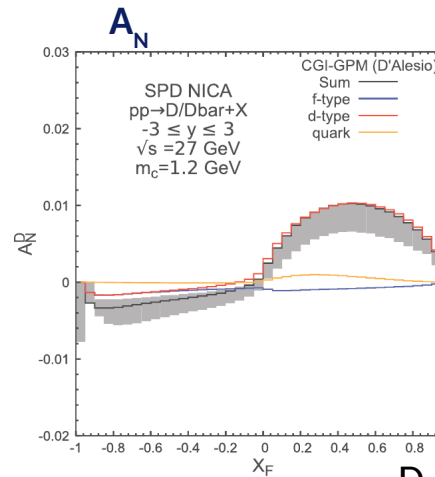
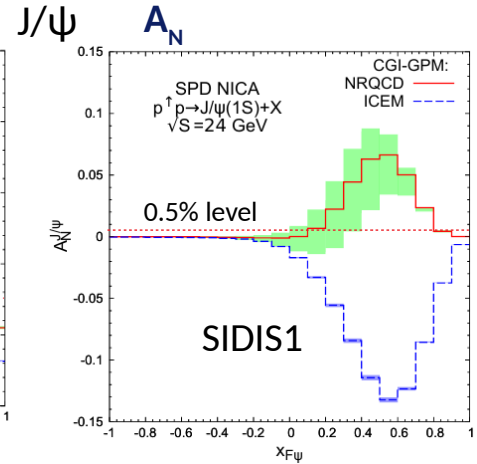
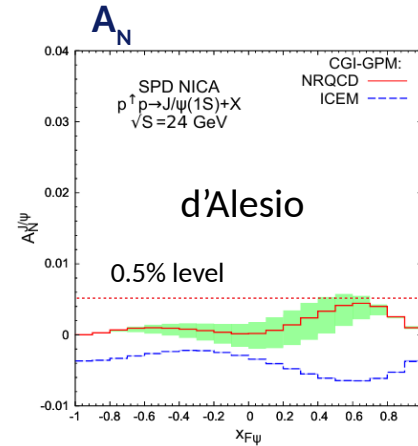
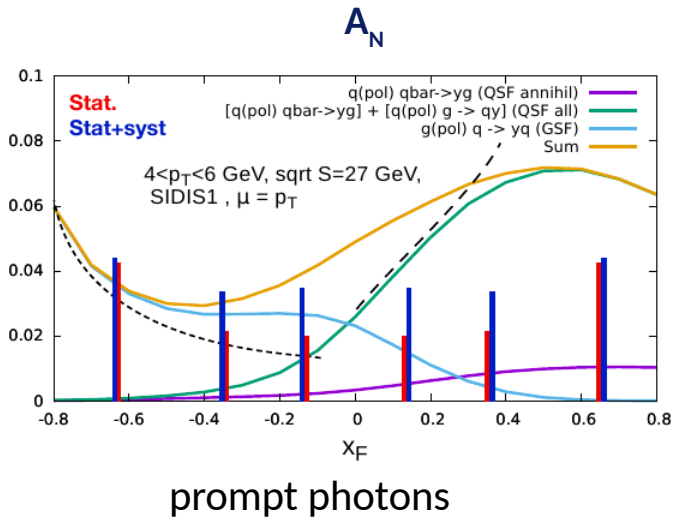
On the physics potential to study the ... deuteron at

U. D'Alesio^{g,h}, M. Deka^a, ...
kov^a, k 오, A. Karpishkov^l,
erg^q, Keh-Fei Liu^r ... O.

Theoretical predictions, precision of our measurements and
their impact

Predictions & expected precision of our measurements

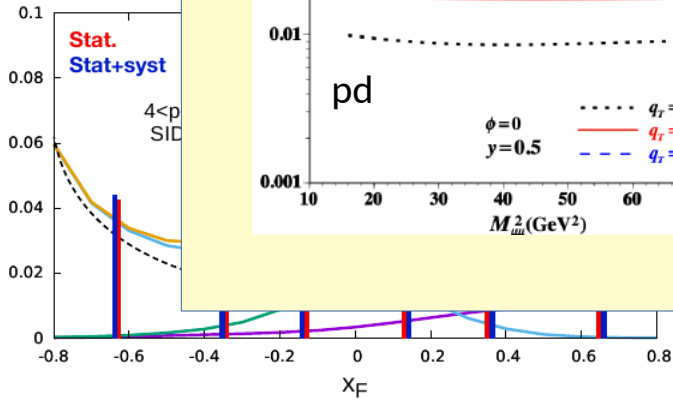
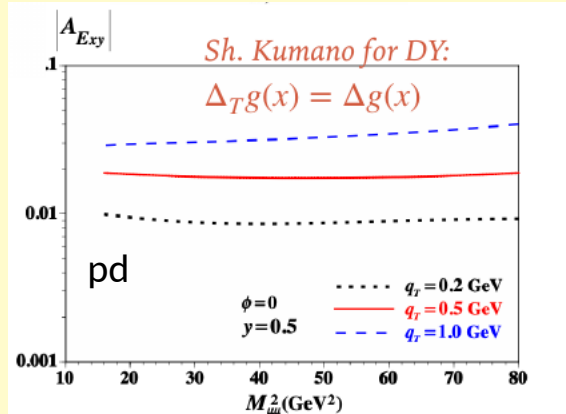
- For our main probes of nucleon gluon structure we have predictions for **proton** collisions (thanks to the Samara group, prediction for A_N are shown)



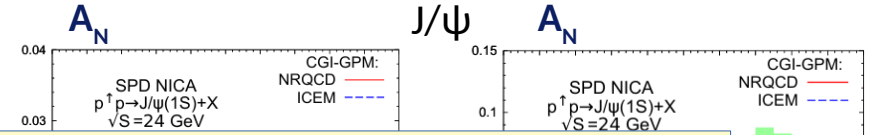
Predictions & expected precision of our measurements

- For our structure function predictions

No predictions for **deuteron** collisions!

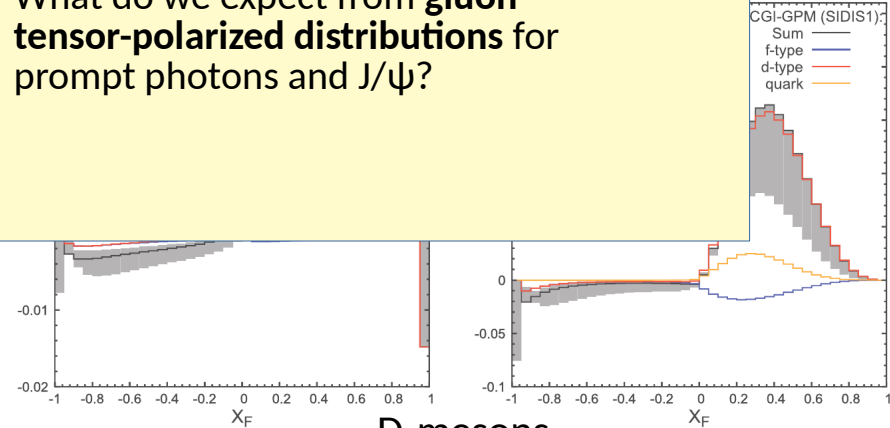


prompt photons



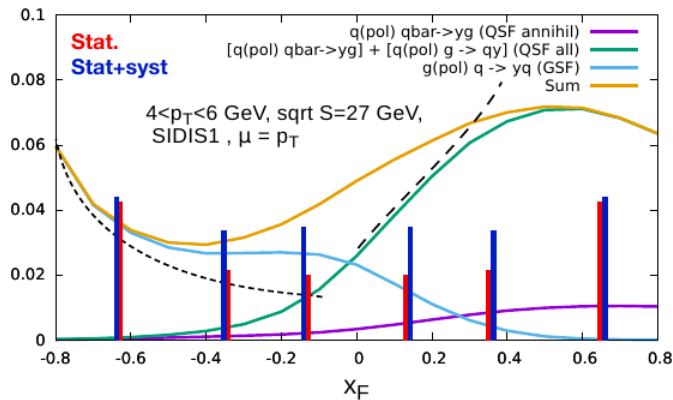
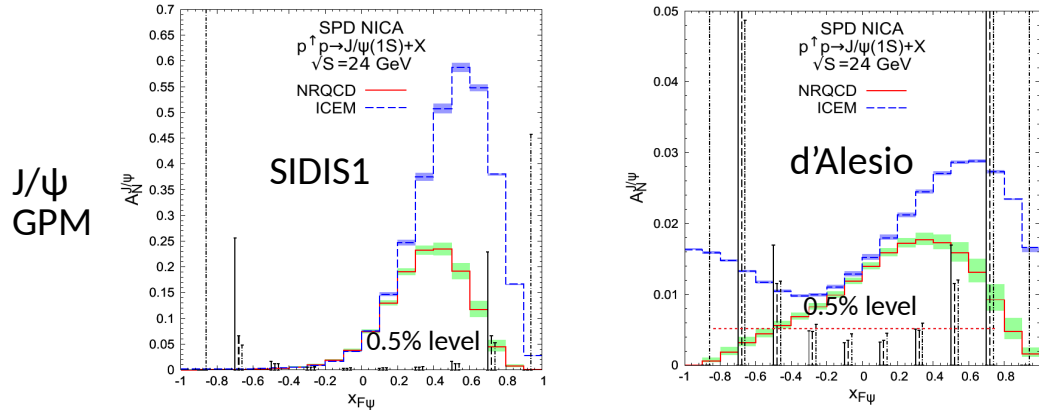
What do we expect from **gluon transversity** for E_{xy} and A_{TT} for our probes in dd collisions?

What do we expect from **gluon tensor-polarized distributions** for prompt photons and J/ψ ?

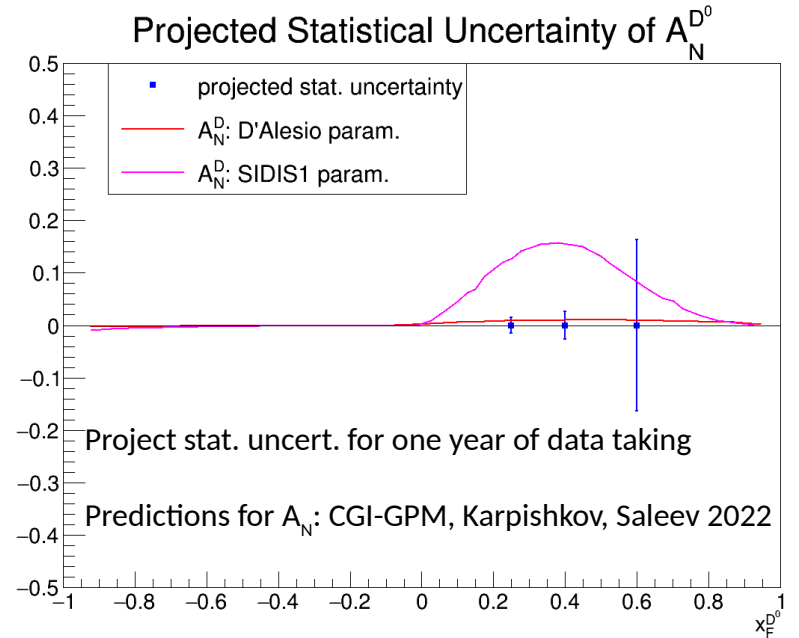


Expected precision of our measurements

Projected stat. uncertainties and predictions from PRD104, 016008 (2021)



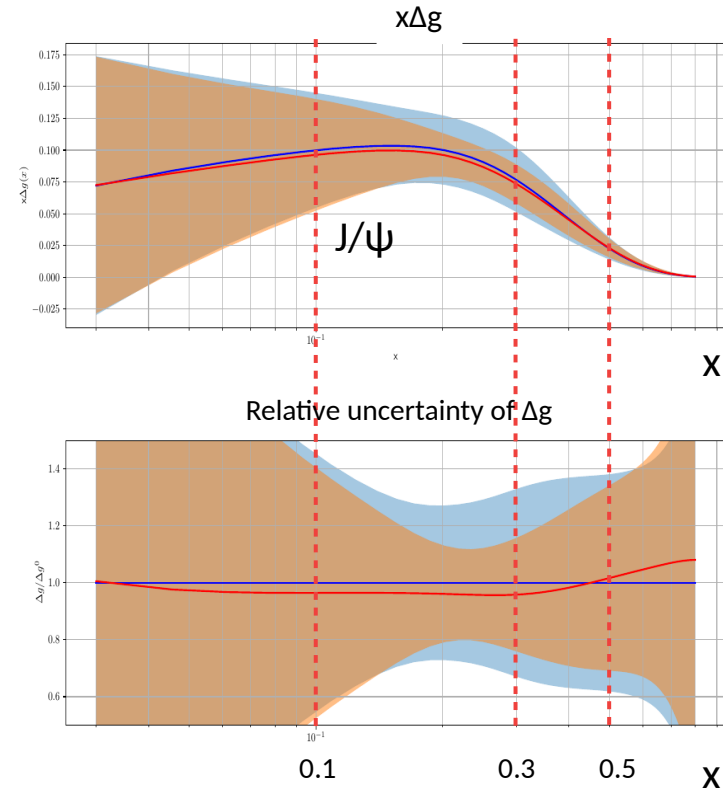
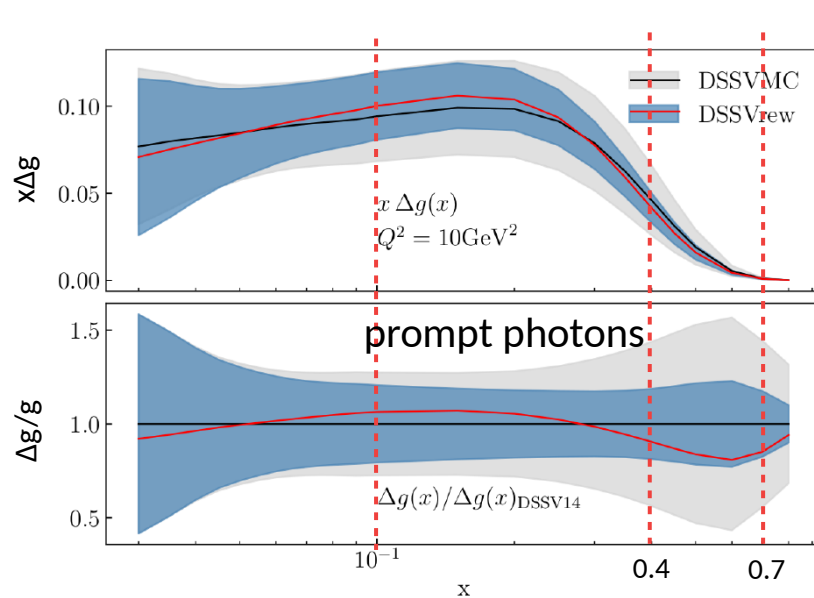
prompt photons



The statistical uncertainties for D^+ will be discussed by Amresh Datta on Wednesday.

Impact SPD measurements (gluon helicity from A_{LL})

Impact of SPD **prompt photon** and **J/ψ ALL** measurements on gluon helicity distributions (for one year of data taking) obtained via **Bayesian reweighing of MC replicas**



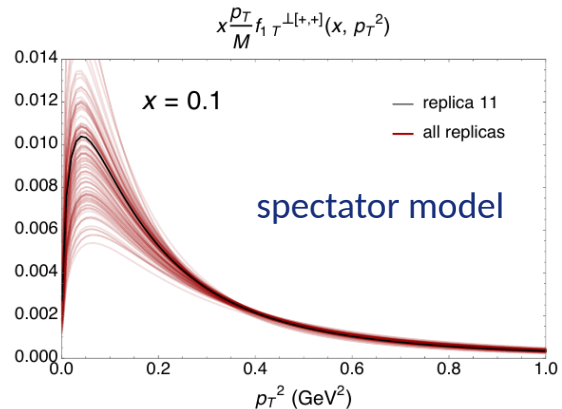
Predictions with new “data” added (top) and ratio of the uncertainties (bottom).
Courtesy R. Sassot, I. Borsa, 2021.

I. Denisenko, last CM

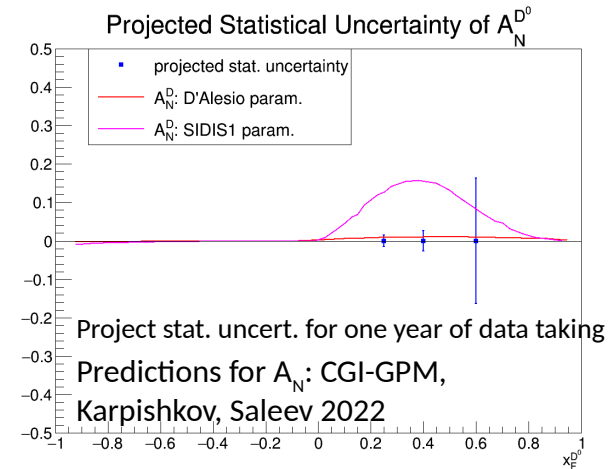
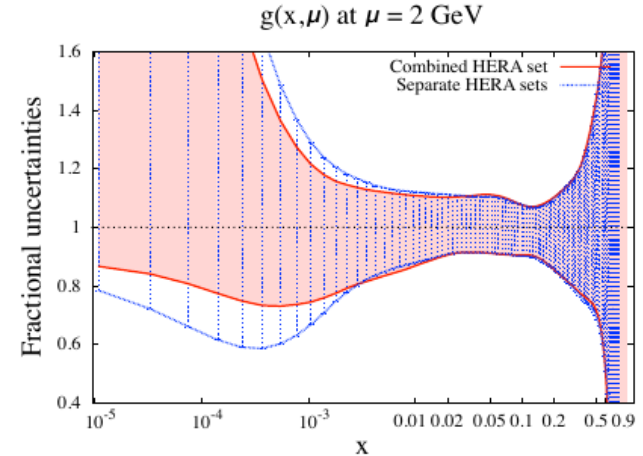
Impact SPD measurements (to do)

What is not estimated:

- Impact on **unpolarized gluon PDF**
- Impact of measurements with **open charm**
- Is it possible to estimate impact of our A_N measurements for extraction/constraining of the **GSF** (call for theorists!)?



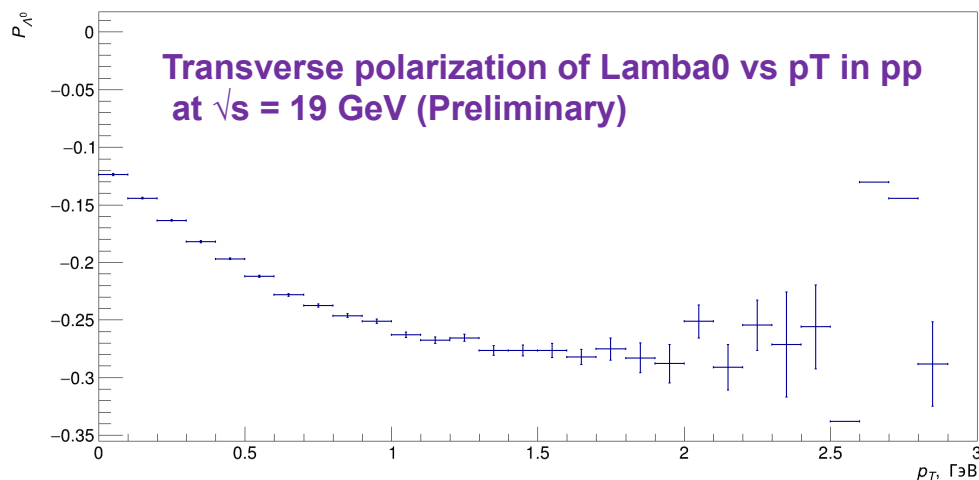
p_T -dependence for f-type Sivers TMD in the **spectator model**,
Bacchetta, Celiberto, Radici, 2022



Simulation, reconstruction, and analysis

Work with generators

- **ULYSSES** (multiquark correlations) – A. Zelenov, V. Kim, work in progress
- Simulation lambda polarization effects in unpolarized pp collision (V. Kim, A. Sergeev)
- Polarized collisions with **SPHINX** (see talk by Vadim Alexakhin on Wednesday)
- Code to **import of HepMC** as a SpdRoot generator **would be useful**



PNPI: V.T. Kim, A.V. Sergeev

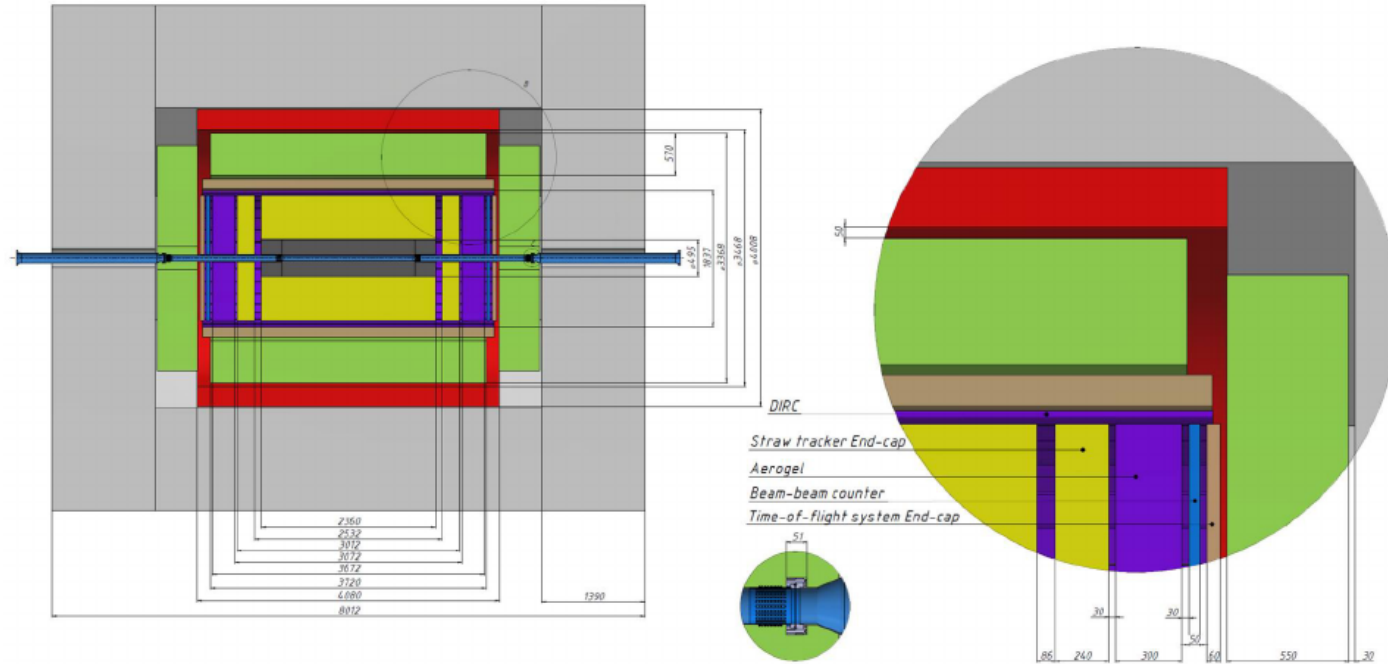
Transverse polarization of Lambda0 in pp-collisions

In spirit of instanton vacuum model by M.G. Ryskin (1988)

Pythia8-based code: A.V. Sergeev

SpdRoot: update to 4.1.6.1

Geometry update (geometry and position): RS, ECal, Magnet, BBC, TOF, AEG, TS endcaps.



- New Cherenkov detector in barrel (DIRC)
- Radial 10 cm: +2 cm to Magnet, +2 cm to ECal, +6 cm to DIRC
- Longitudinal 30 cm: Width of Aerogel detector increased 16 cm → 30 cm

From A. Korzenev at the spring CM

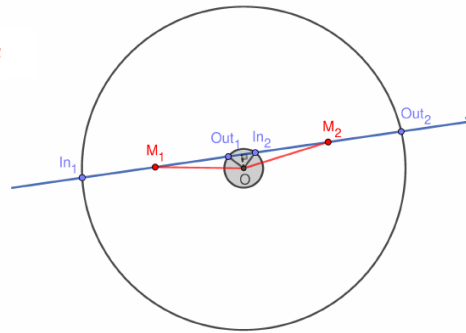
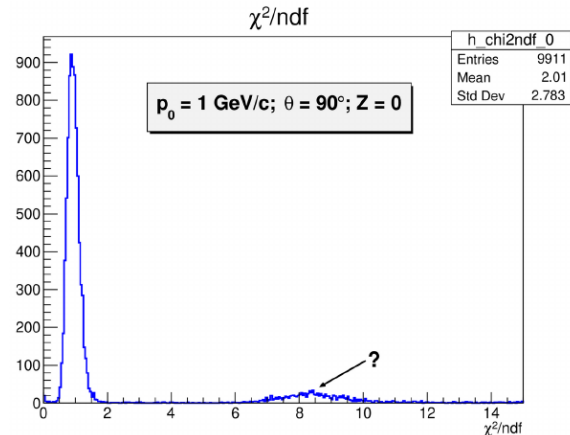
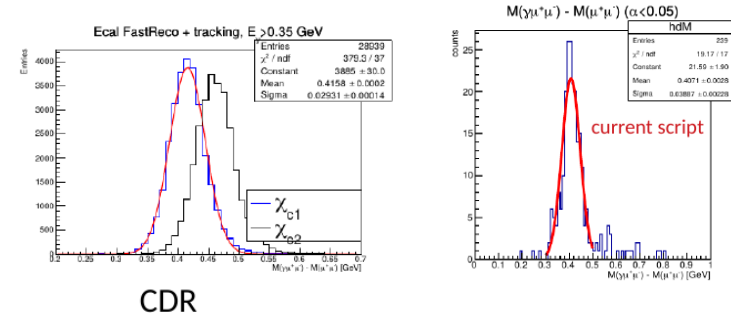
SpdRoot: update to 4.1.6.1

TOF PID parameters updated for new geometry.

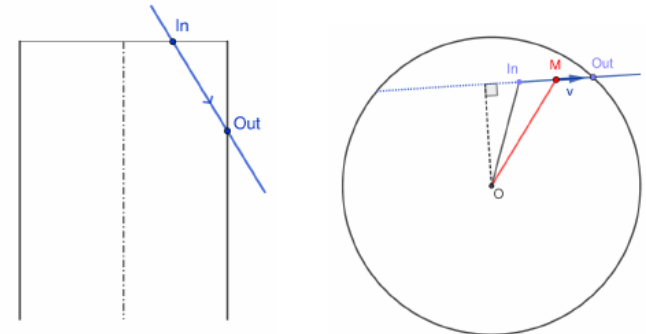
Simulation scripts update: jpsi-mumu, chic. The jpsi-ee example is removed
Secondary vertex reconstruction task should be switched to
SpdRCKFpartVOFinder

Fixes:

- chi2 between tracks fixed in KFParticle
- An issue with ECal helper (Ruslan's talk Physics Weekly 19.09.23)
- For the situation when track crosses the wire in straw the Ruslan's **partial solution** is adopted (Ruslan's talk Physics Weekly 19.09.23)



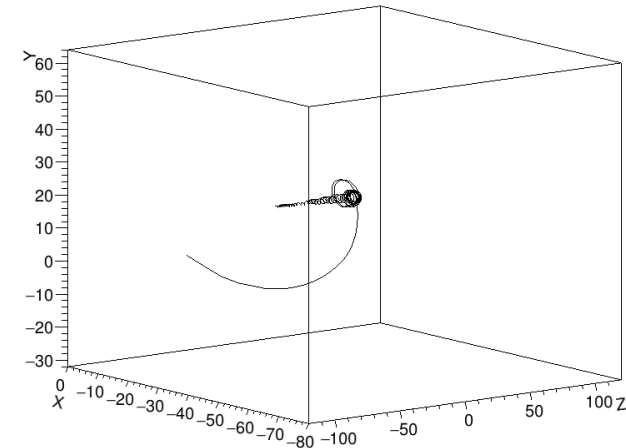
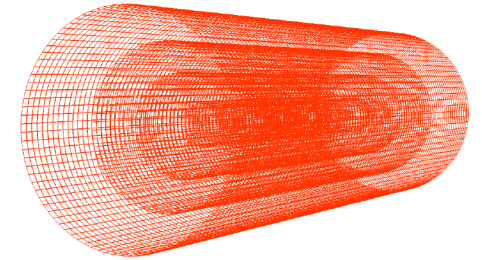
Need input from straw group!



R. Akhunzyanov at Physics Weekly 19.09.23

SpdRoot: next steps

- **Vertex detector:** separate DSSD and MAPS description in the code; optimization of the geometry of the MAPS tracker
- **Track finding:** move towards realistic track reconstruction
- **Track fitting and hit creation:** proper physical treatment of cases mentioned at the last slide; moving to use realistic r-t curve
- **Primary vertex fitting:** moving to KFParticle to remove limitations for perpendicular tracks and to be able to quickly add/remove tracks in D-meson search
- **Secondary vertex:** split to search of K_S/Λ vertices during default reconstruction and search for D-mesons or Λ_c in the user analysis stage
- **Track/ECal cluster association**
- **Combinatorial hits** from strip-like detectors (DSSD, MVD)
- **Removal of MC-truth usage** at any stage of the event reconstruction.
- **Performance:** exclude pathological tracks from track fitting (for the suggestion by V. Lyubushkin it can reduce time by a factor of ~ 3)
- **Validation tests for each part of event reconstruction!**



Example of “bad” track after ideal pattern recognition (V. Lyubushkin)

Reconstruction in SpdRoot

Reconstruction task	Can be used for analysis?	Contact person	Note
Pattern recognition (MAPS+Straw)	±	V. Andreev	slow, not be applicable for DSSD and Micromegas-based central tracker
Pattern recognition from ST to VD or CT		Nikolay Voytishin Mihai Dima	see talk at the software section
Track fitting	+	V. Andreev R. Akhunzyanov	requires optimization, update with constraint fit validation and performance tests
Primary vertex finding & fit	+	V. Andreev E. Zemlyanichkina	see talk by Vladimir validation scripts required
Secondary vertex fit	±	V. Andreev	validation scripts update required
dE/dx PID	+	R. Akhunzyanov	idealistic case
TOF FARICH PID	+	A. Ivanov	simplified approach work on FARICH modeling started (talk by Artem)
Pattern recognition in ECal	+	A. Maltsev	barrel-endcap cluster bridging (see talk by Andrey)
Energy reconstruction in Ecal	+	A. Maltsev	
pion/photon separation for high E	+	A. Maltsev	
PID in RS	-+	I. Eleckih A. Gridin	ongoing work, Kalman-tree-like method – slow more realistic hit reconstruction
Energy estimation in in RS		A. Verkheev	see talk by Alexander

Reconstruction in SpdRoot

Reconstruction task	Can be used for analysis?	Contact person	Note
Pattern recognition (MAPS+Straw)	±	V. Andreev	slow, not be applicable for DSSD and Micromegas-based central tracker
Pattern recognition from ST to VD or CT			
Track fitting			ch constraint fit
Primary vertex finding & fit			
Secondary vertex fit			
dE/dx PID			
TOF			
FARICH PID			
Pattern recognition in ECal			ee talk by Andrey)
Energy reconstruction in Ecal			
pion/photon separation for high E			
PID in RS	-+	I. Eleckih A. Gridin	ongoing work, Kalman-tree-like method – slow more realistic hit reconstruction
Energy estimation in in RS		A. Verkheev	see talk by Alexander

Valuable contributions can be made to

- more realistic dE/dx simulation
- proper reconstruction (with combinatorial hits for “strip”-like detectors) for MCT, DSSD
- moving to more realistic simulation
- tracking optimization,
- more realistic TOF PID (e.g. using approach for T0 of S. Yurchenko)
- reconstruction for aerogel threshold counters and FARICH,
- ...

Modeling of physical processes (1-st stage)

Process	Person	Note
Elastic pp and dd scattering	A. Gridin, A. Terkulov	
Problems of soft pp interactions	A. Galoyan	
Single spin physics	R. Akhunzyanov, N. Rogacheva, E. Zemlyanichkina	acceptances, efficiencies, and yields for π^0 , K_S , and charged particles (see talks by Natalie and Elena)
Vector light and charm meson production		effect of absorber instead of ECal at 1-st stage
Exclusive reactions with lightest nuclei and spin observables		
Multiquark correlations and exotic hadron state production	A. Galoyan, A. Zelenov	
Exclusive hard processes with deuteron		
Search for deconfinement in pp and dd central collisions		
Search for dibaryons	V. Kurbatov	
Search for lightest neutral hypernuclei with strangeness -1 and -2		START report by M. Davydov
Measuring antiproton production cross-section for dark matter search		
Hadron formation effects in heavy ion collisions		START report by R. Pandey
Polarization of hyperons		
Soft photons	E. Kokoulina's group	
Bose-Einstein condensation and correlation	E. Kokoulina's group	
Quark-instanton scattering		missing note for the seminar

Modeling of physical processes

2-nd stage physics

Process	Person	Note
Inclusive charmonia production	A. Karpishkov, I. Denisenko, V. Shalaev, I. Zhizhin A. Anufriev	
Inclusive η_c production		see talk by Anton
Associate $J/\psi\gamma$	L. Alimov N. Ospennikov	see talk by Lev
Inclusive open charm (D-mesons)	A. Datta, V. Andreev	see talk Amaresh for results on D+
Study of Λ_c signal at SPD	A. Smirnov, L. Seryogin	the first estimates (see talks)
Search for exotic $ss\bar{s}\bar{s}$ state	L. Seryogin	see talk by Leonid
Search for glueball candidates		
Open charm from $D\mu$ and inclusive muons	A. Skachkova	ongoing generator-level studies
Prompt photons	A. Guskov, A. Datta	
Cluster particle production	D. Budkouski, A. Tumasyan	see talk by Dmitry

Online polarimetry

Process	Person	Note
Online polarimetry with BBC	Zh. Kurmanaliev, A. Terekhin	see talk by Arkadiy
Online polarimetry with π_0	K. Shtejer	note preparation
Online polarimetry with ZDC	N. Zhigareva, P. Alekseev	

Modeling of physical processes


2-nd stage physics

Process	Person	Note
Inclusive charmonia production	A. Karpishkov, I. Denisenko, V. Shalaev, I. Zhizhin A. Anufriev	see talk by Anton
Inclusive η_c production		
Associate $J/\psi\gamma$	L. Alimov N. Ospennikov	see talk by Lev
Inclusive open charm (D-mesons)	A lot of opportunities to contribute: <ul style="list-style-type: none">• exclusive processes,• multiquark correlations,• nuclear physics tasks• search for glueball candidates• ... For details see: <ul style="list-style-type: none">• Progress in Particle and Nuclear Physics 119, 103858 (2021)• Physics of Particles and Nuclei 52, 1044 (2021)• SPD meetings, seminars	on D+
Study of Λ_c signal at SPD		
Search for exotic $ss\bar{s}\bar{s}$ state		
Search for glueball candidates		
Open charm from $D\mu$ and inclusive muons		es
Prompt photons		
Cluster particle production		
Online polarimetry		
Process		
Online polarimetry with BBC		
Online polarimetry with π^0		
Online polarimetry with ZDC	N. Zhigareva, P. Alekseev	

- **Using the docker image for for running SpdRoot is strongly recommended.**
- The examples mentioned before have been updated to simplify the first steps with SpdRoot.
- SpdRoot is very resource consuming for both CPU and storage. Production would much simplify many analyses.
- Possibility to create accounts for SPD members from other universities would much facilitate our work.
- Make sure that you set the random seed via gRandom!

- Computing group performed tests and was **ready to start production approximately two weeks ago**. Due to identified bug in SpdRoot start of the production has been postponed.
- **I see a critical need to do large scale production for open charm studies:**
 - **minimum bias sample, ~1 billion events;**
 - exclusive open charm ($D^0 \rightarrow K\pi$, $D^+ \rightarrow K\pi\pi$) sample, ~10 million events;
 - both tracker configurations + PID information are required;
 - other tracker configuration may be considered.
- Similar large scale simulation can be performed for charmonia
 - exclusive $J/\psi \rightarrow \mu^+\mu^-$, ~ 10 million;
 - minimum bias (same sample);
 - tracker, ECal, RS.
- **Please send me your needs or suggestions!**

Agenda of Physics at CM (Monday, 23.10)

14:00	Lunch break <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	13:30 - 14:30
15:00	Novel results for gluon TMDs in nucleon <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	<i>Dr Valery Lyubovitskij</i> 14:30 - 15:10
	Double spin correlations in the reaction $dd \rightarrow pnpn$ and its relation to pn-correlations <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	<i>Yury Uzikov</i> 15:10 - 15:35
	Active role of gluon in hadron interactions <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	<i>Prof. Elena Kokoulina</i>  15:35 - 16:00
16:00	Coffee break <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	16:00 - 16:30
	Physics of Relativistic Ion-Ion Collisions: SPD Opportunities <i>Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara</i>	<i>Grigory Nigmatkulov</i> 16:30 - 17:00

Agenda of Physics at CM (Wednesday, 25.10)

SPD grants part

10:00	Report on Samara group activity Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Prof. Vladimir Saleev 10:00 - 10:25
	Report on MSU group activity Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Alexandr Berezhnoy 10:25 - 10:35
	Study of multiquark fluctons in dd collisions at SPD Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Vladimir Vechernin 10:35 - 11:00
11:00	Associated $SJ/\psi+\gamma$ production at the SPD NICA Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Lev Alimov 11:00 - 11:15
	On η_c production at the SPD NICA Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Anton Anufriev 11:15 - 11:30
	Coffee break Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	11:30 - 12:00
12:00	Open charm production at low energies: short review and some ideas worth trying at SPD conditions. Evgeniy Leshchenko	
	Λ_c^+ observation possibility at SPD NICA experiment Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Artem Smirnov 12:15 - 12:30
	Λ_c production simulation and $d\text{-}\psi$ production simulation within SPDRoot Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Leonid Seregin 12:30 - 12:45
13:00	Spin-dependent event simulation Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Vadim Alexakhin 12:45 - 13:05
	A new algorithm for reconstruction of the primary vertex of interaction Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Vladimir Andreev 13:05 - 13:30
	Lunch break	

15:00	Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	13:30 - 14:30
	Track fitting performance in SpdRoot Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Ruslan Akhunzyanov 14:30 - 14:50
	Particle Identification in SPD Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Artem Ivanov 14:50 - 15:05
16:00	Charged particle yields Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Elena Zemlyanichkina 15:05 - 15:20
	Study of KS meson reconstruction efficiency at SPD Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Natalia Rogacheva 15:20 - 15:35
	Status of reconstruction in SPD ECAL Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Andrei Maltsev 15:35 - 15:55
17:00	Coffee break Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	16:00 - 16:30
	Status of the Description of the Muon System in the SpdRoot Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Alexander Verkheev 16:30 - 16:45
	Realistic hit reconstruction in SPD muon system Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Andrei Gridin 16:45 - 17:00
17:00	Cluster particle production @SPD experiment Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Dzmitry Budkouski 17:00 - 17:20
	Prospects of open charm measurements at SPD Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Amaresh Datta @ 17:20 - 17:40
	Simulation of the pp-scattering for the SPD BBC Auditorium L11, Building 22B, Samara University, Academician Pavlov str., 1, Samara	Arkadiy Terekhin 17:40 - 18:00

- The physics case for SPD broadens (study of sum rules for TMDs, physics light to moderate nuclei).
- For estimation of impact of our measurements and observables in dd collisions help from theoreticians would be much appreciated.
- We are moving forward in detector and physics simulation, improve our simulation software. There are a lot of places to contribute. Work on improving simulation, reconstruction, their validation, maintaining geometry and analysis tools in SpdRoot is a basement for future MC studies. I tried to make an overview of the **current situation** and **suggested tasks**.
- The SPD grants and the START program helped to involve more people and especially students in physics at SPD.
- Gaudi-based framework is developing is not fast (help would be appreciated).

Thank you!