The SPD project

at the Laboratory of High Energy Physics, Joint Institute for Nuclear Research, Dubna

Polarization data has often been the graveyard for fashionable theories. If theorists had their way they might well ban such measurements altogether out of self-protection.

J.D. Bjorken, 1987

Roumen Tsenov (LHEP),

for the SPD project team

NICA (Nuclotron based Ion Colider fAcility) is the flagship project in high energy physics of the Joint Institute for Nuclear Research

Main targets of the NICA project:

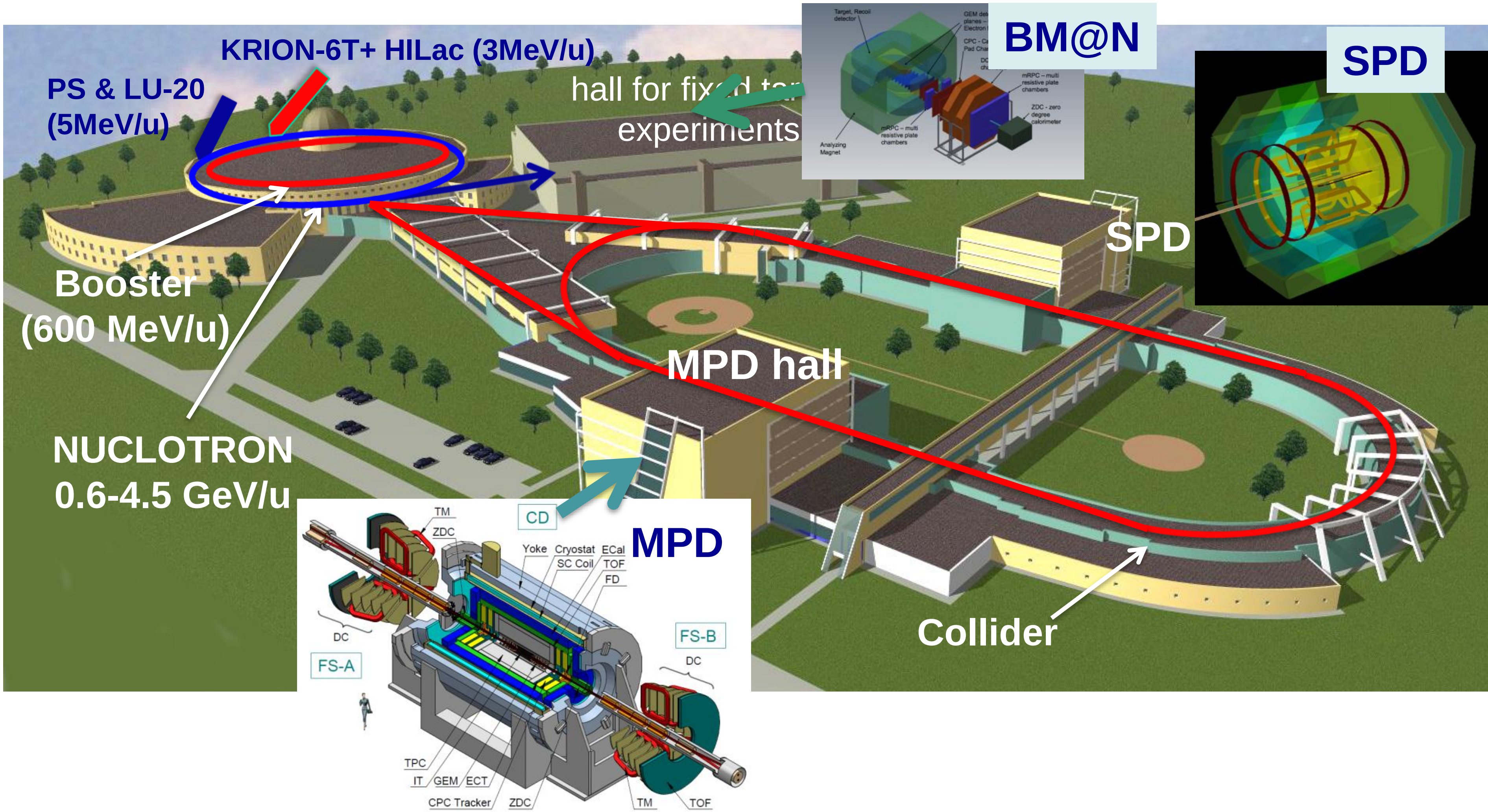
- ***study of hot and dense baryonic matter***
- ***investigation of nucleon spin structure, polarization phenomena***

Ring circumference, m	**503.04**
heavy ions	
energy range for ***Au***$^{79+}$*:* $\sqrt{S_{NN}}$*, GeV*	**4 - 11**
r.m.s. $\Delta p/p$, 10^{-3}	**1.6**
Luminosity for ***Au***$^{79+}$*, cm*$^{-2}$ *s*$^{-1}$	**1x10^{27}**
polarized particles	
max. $\sqrt{S}$ *for polarized* ***p****, Gev*	**27**
Luminosity for ***p****, cm*$^{-2}$ *s*$^{-1}$	**1x10^{32}**

The NICA complex

existing facilities

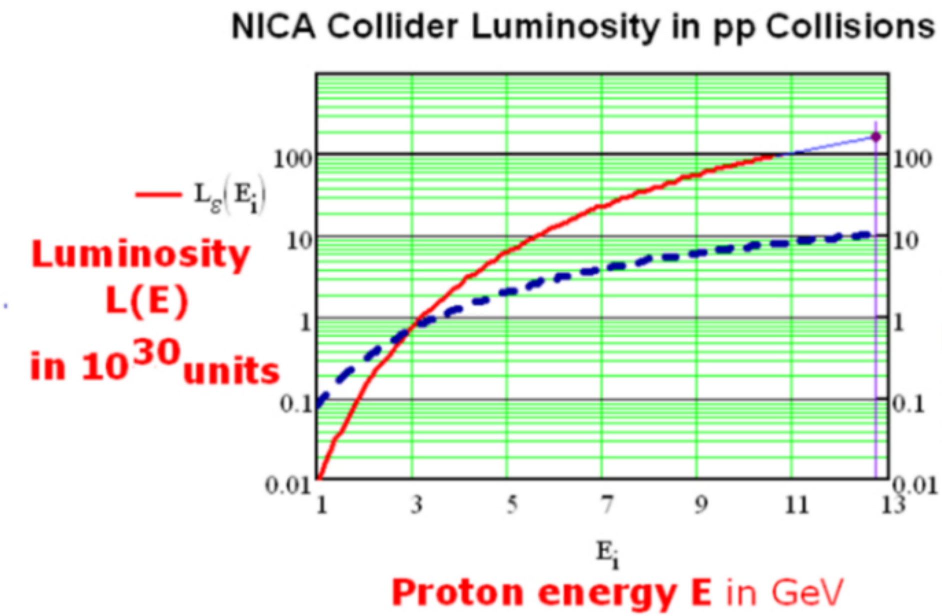
to be constructed



Civil Construction, bld.17

June 2018

Polarized beams



$L_{peak} \approx 1.8 \cdot 10^{32}\ cm^{-2} \cdot s^{-1}$

particle number per bunch in 10^{11} units

maximum proton number in each ring – $2.2 \bullet 10^{13}$

Bunch crossing each 80 ns; crossing rate 12.5 MHz .

circumference - 503 m,

number of intersection points (IP) - 2,

beta func

number

number

RMS bu

incoherent tune shift, $\Delta_{Lasslett}$ - 0.027,

beam-beam parameter, ξ - 0.067,

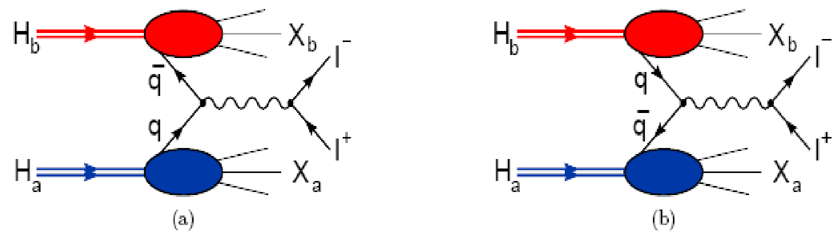
beam emittance ε_{nrm} , π mm mrad - 0.15 (normalized at 12.5 GeV).

Polarized beams

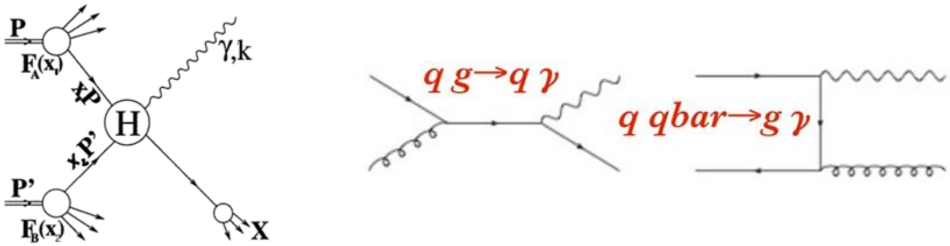
- **p↑p↑** at $\sqrt{s_{pp}}$ **= 12 - 27 GeV, L_{av}** ≈ $10^{32}\ cm^{-2}s^{-1}$
- **d↑d↑** at $\sqrt{s_{NN}}$ **= 4 - 13 GeV**
- *longitudinal and transverse polarization in SPD and MPD*

Physics tasks

- ▶ **Nucleon spin structure studies**
  - **Drell-Yan pair production;**



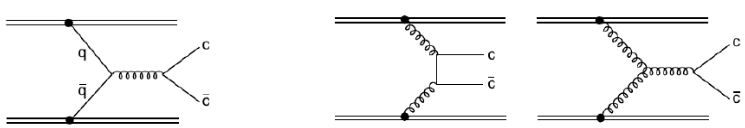
  - **Direct photons;**



▪

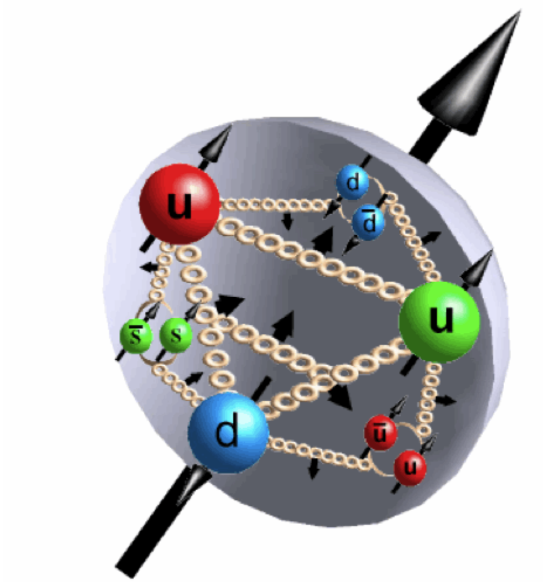
  - **Nucleon PDFs by J/ψ production;**

LO $c\bar{c}$ production diagram:

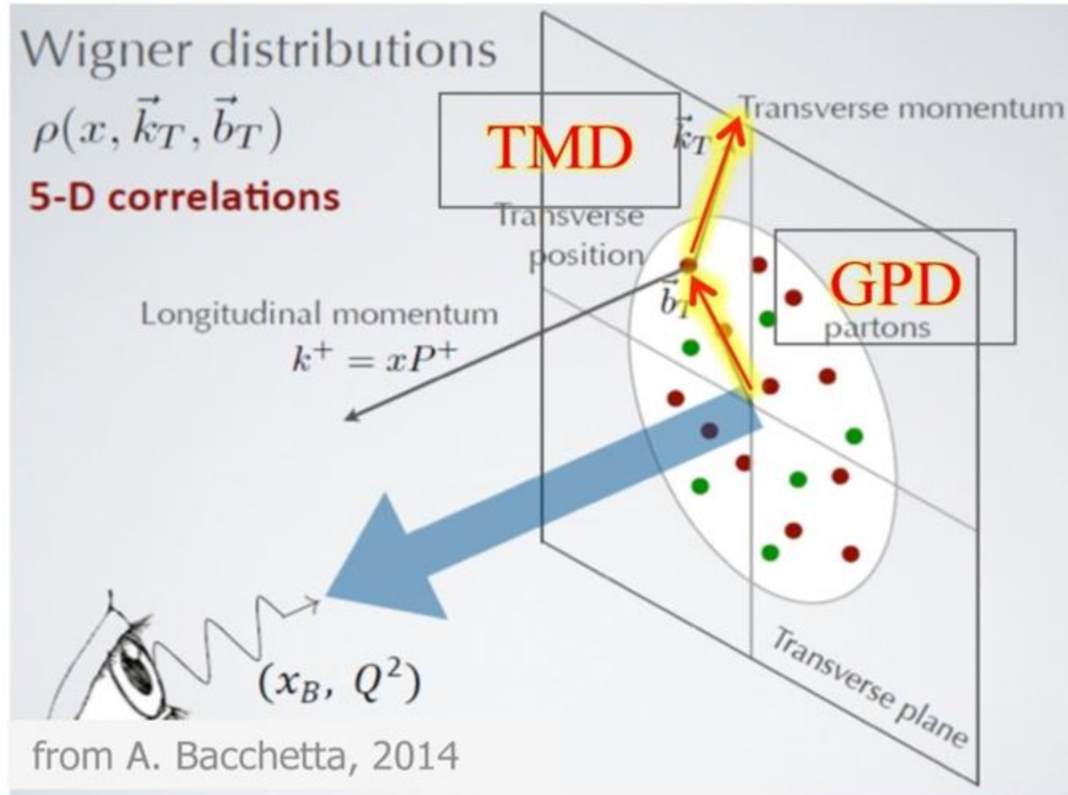


- ▶ **Spin-dependent effects in elastic pp, pd and dd scattering;**
- ▶ **Spin effects in exclusive hadron production;**
- ▶ **Spin effects in production of hadrons with high p_T ;**
- ▶ *etc….*

Spin dependent PDFs



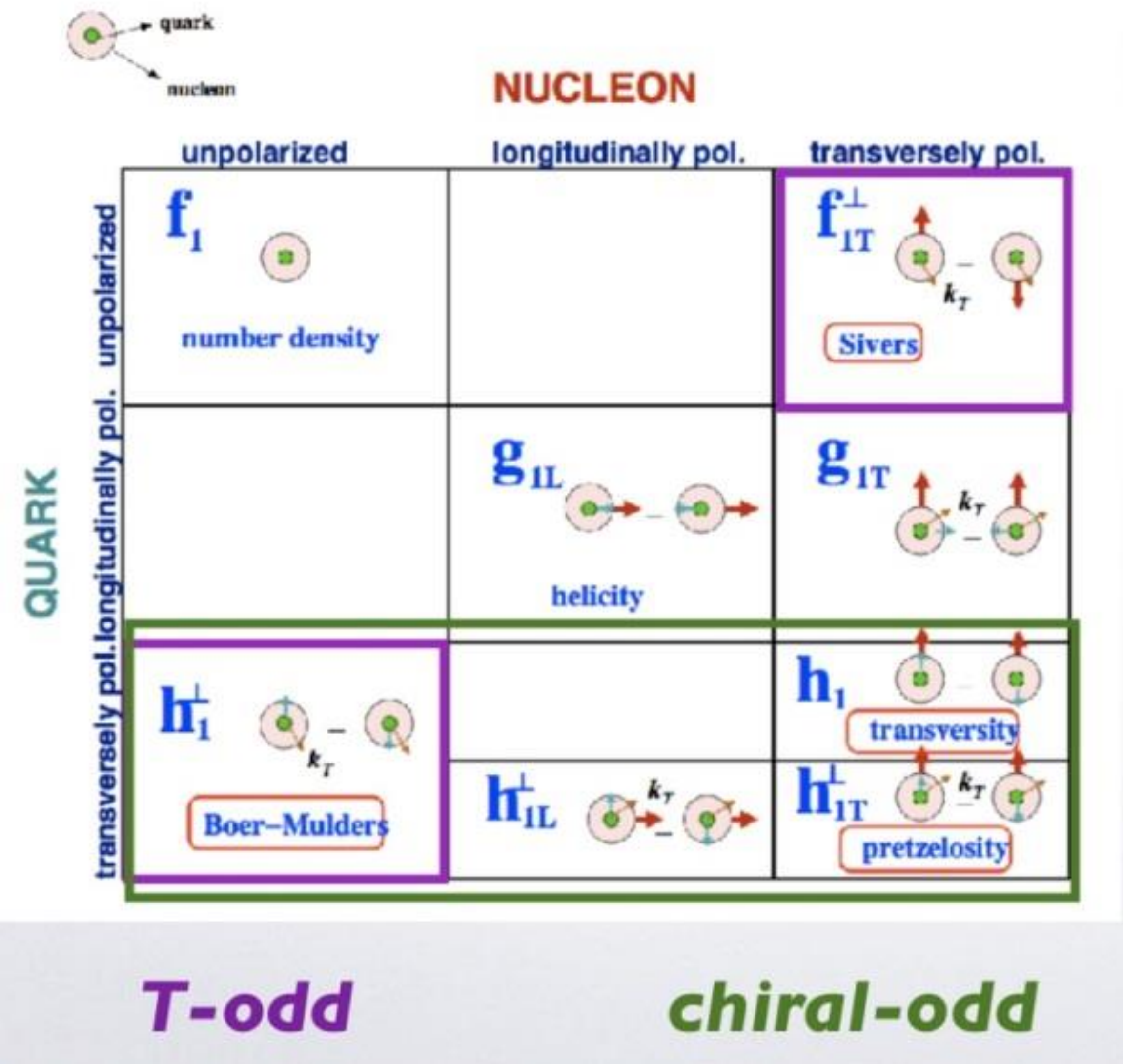
$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g.$$



Transversity Momentum Distributions: TMD (x,k_T)
probe the transverse parton momentum dependence

Generalized Parton Distributions : GPD (x,b_T):
probe the transverse parton distance dependence

TMD and GPD



3 PDFs are needed to describe nucleon structure in collinear approximation

8 PDFs are needed if we want to take into account intrinsic transverse momentum k_T of quarks

Structure functions

1. Transversity: $A_{UT}^{\sin(\phi+\phi_S)}$, represents the number distribution of transversely polarized quarks in a transversely polarized nucleon;

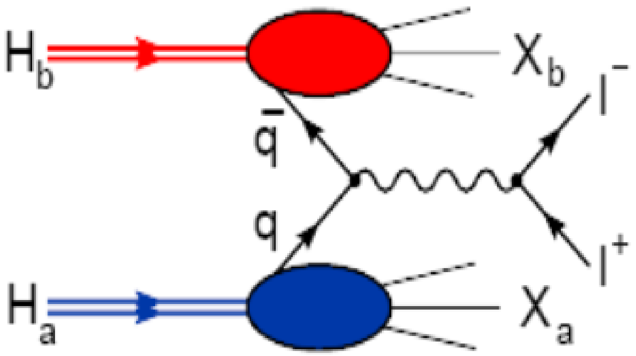
2. Sivers: $A_{UT}^{\sin(\phi-\phi_S)}$, represents the distribution over the transverse momentum of non-polarized quarks in a transversely polarized nucleon;

3. Pretzelosity: $A_{UT}^{\sin(3\phi-\phi_S)}$, represents the distribution over the transverse momentum of transversely polarized quarks in a transversely polarized nucleon;

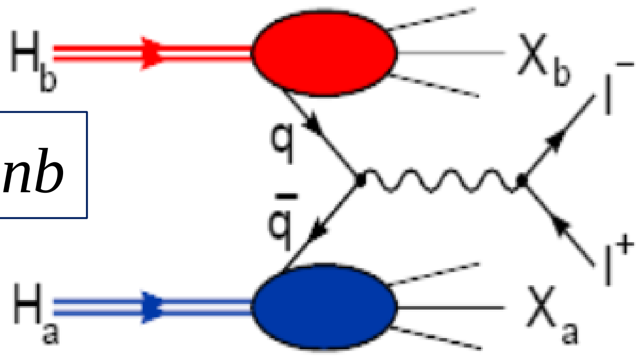
4. Boer-Mulders: $A_{UU}^{\cos(2\phi_h)}$, represents the distribution over the transverse momentum of transversely polarized quarks in a non-polarized nucleon;

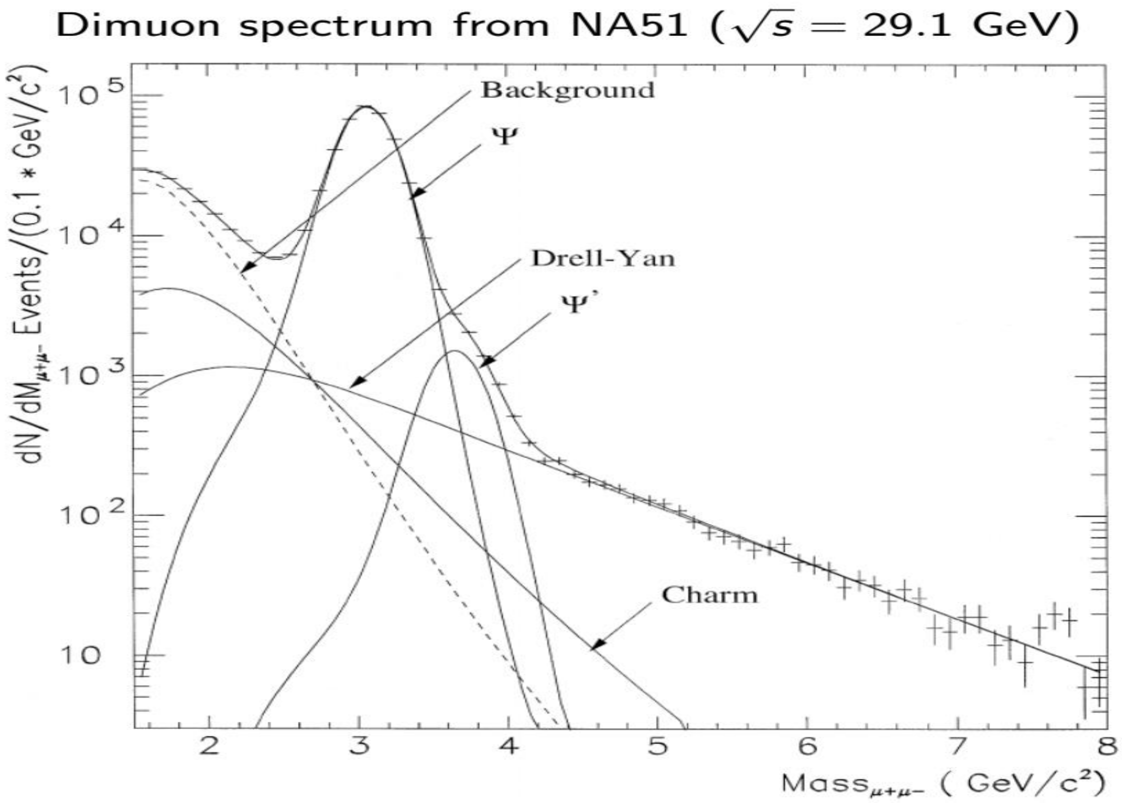
5. Worm-Gears: $A_{UL}^{\cos(2\phi_h)}$, represents the distribution over the transverse momentum of longitudinally polarized quarks in a longitudinally polarized nucleon.

Drell-Yan pairs



$\sigma_{tot} \sim 9\ nb$





COMPASS data, pion beam

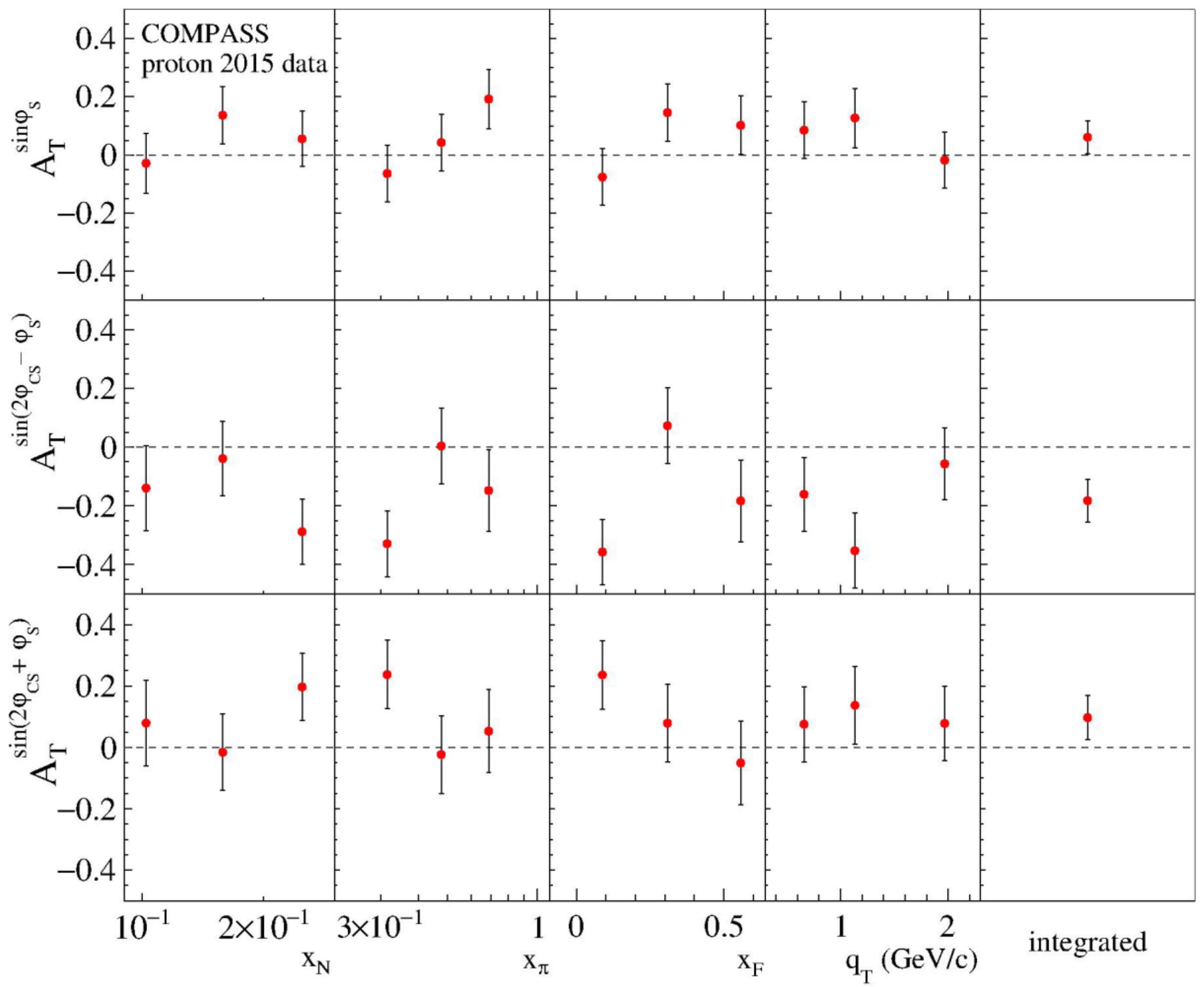
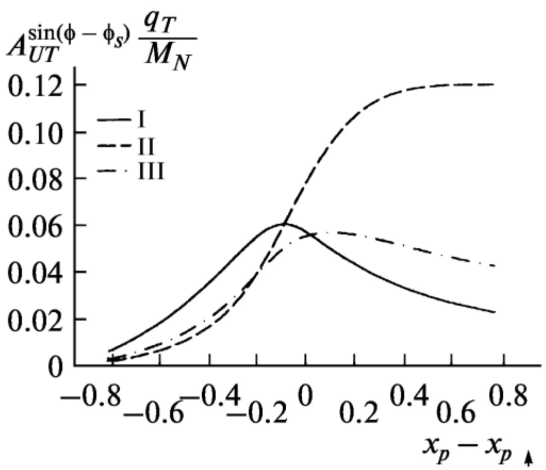
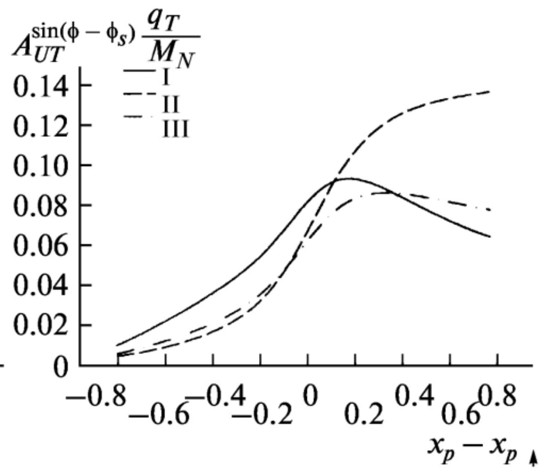


Figure 4: COMPASS data on Drell–Yan pair production spin asymmetries related to Sivers, transversity and pretzelosity TMD PDFs (top to bottom).

Asymmetries in DY pair production

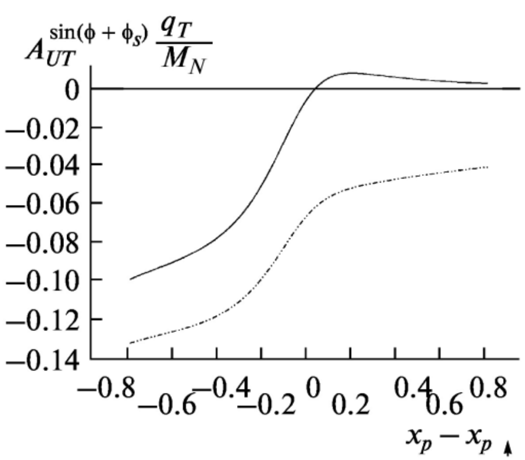
Q^2 = 4 GeV^2 **Q^2 = 15 GeV^2**

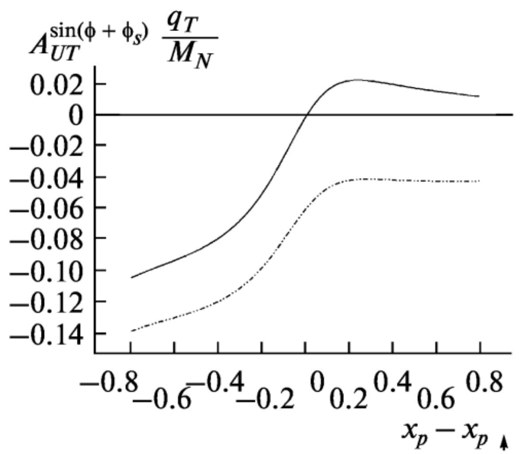




Sivers

J.C.Collins et al., PRD73 (2006)014021



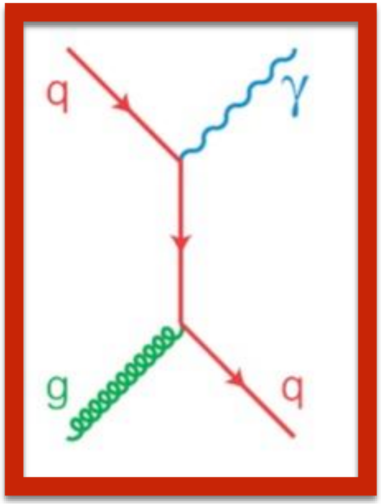


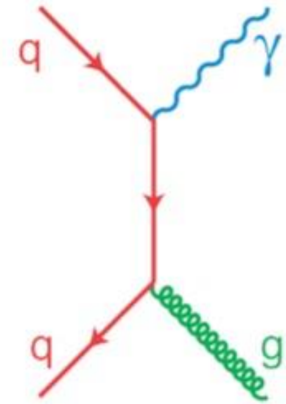
Boer-Mulders

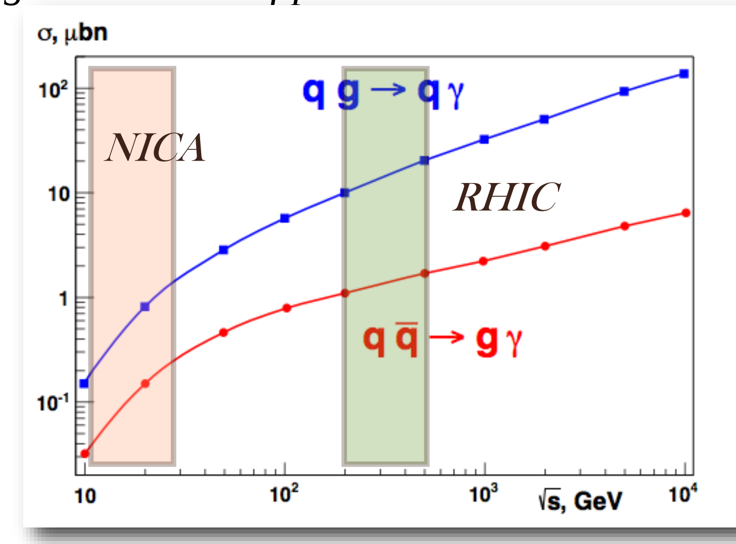
s= 400 GeV^2

Prompt photons

The gluon Compton scattering gives access to the gluon content of proton:







Transverse beam polarization: access to the Sivers function for gluons

$$\sigma^{\uparrow} - \sigma^{\downarrow} = \sum_i \int_{x_{min}}^{1} dx_a \int d^2\mathbf{k}_{Ta} d^2\mathbf{k}_{Tb} \frac{x_a x_b}{x_a - (p_T/\sqrt{s})\, e^y} \left[q_i(x_a, \mathbf{k}_{Ta}) \Delta_N G(x_b, \mathbf{k}_{Tb}) \times \frac{d\hat{\sigma}}{d\hat{t}}(q_i G \to q_i \gamma) + G(x_a, \mathbf{k}_{Ta}) \Delta_N q_i(x_b, \mathbf{k}_{Tb}) \frac{d\hat{\sigma}}{d\hat{t}}(G q_i \to q_i \gamma) \right]$$

Longitudinal beam polarization: access to gluon polarization Δg/g

$$A_{LL} \approx \frac{\Delta g(x_1)}{g(x_1)} \cdot \left[\frac{\sum_q e_q^2 \left[\Delta q(x_2) + \Delta \bar{q}(x_2)\right]}{\sum_q e_q^2 \left[q(x_2) + \bar{q}(x_2)\right]} \right] + (1 \leftrightarrow 2)$$

Prompt photon production cross section

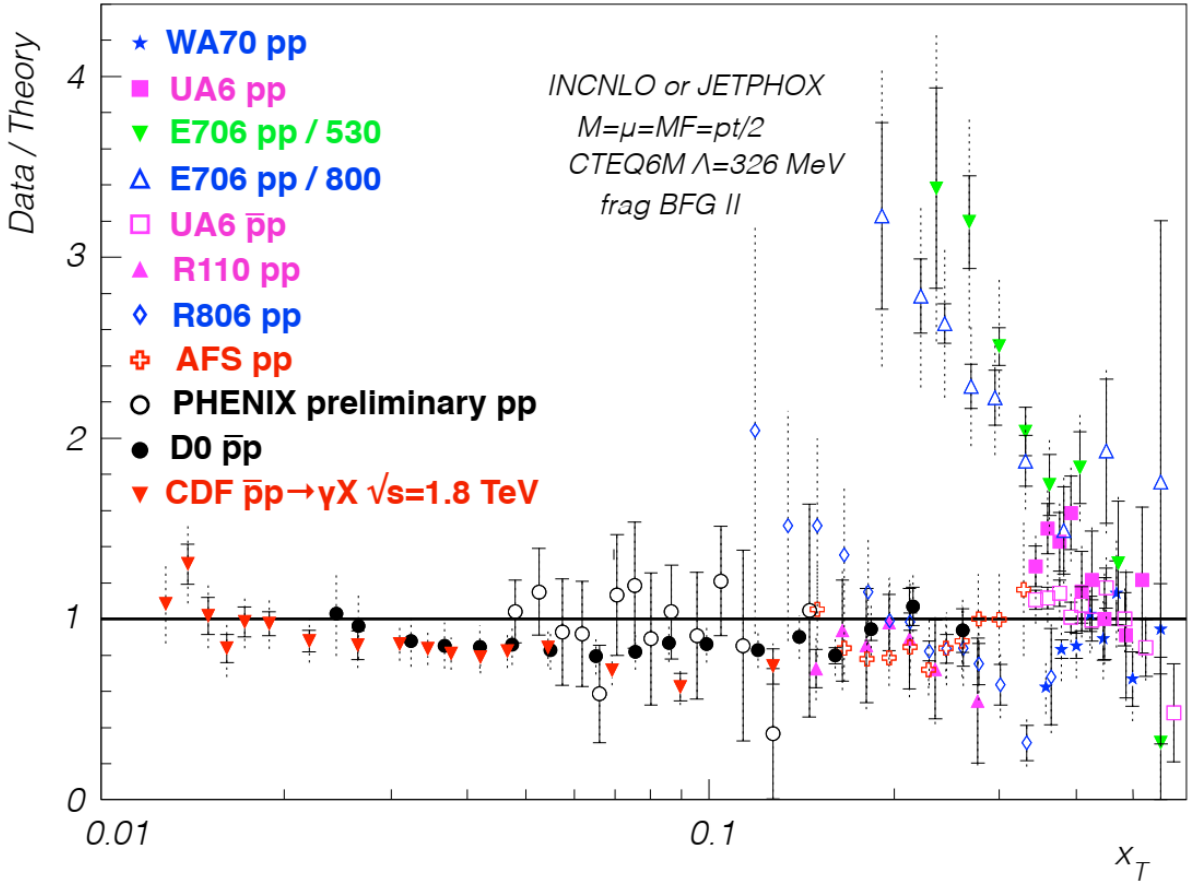
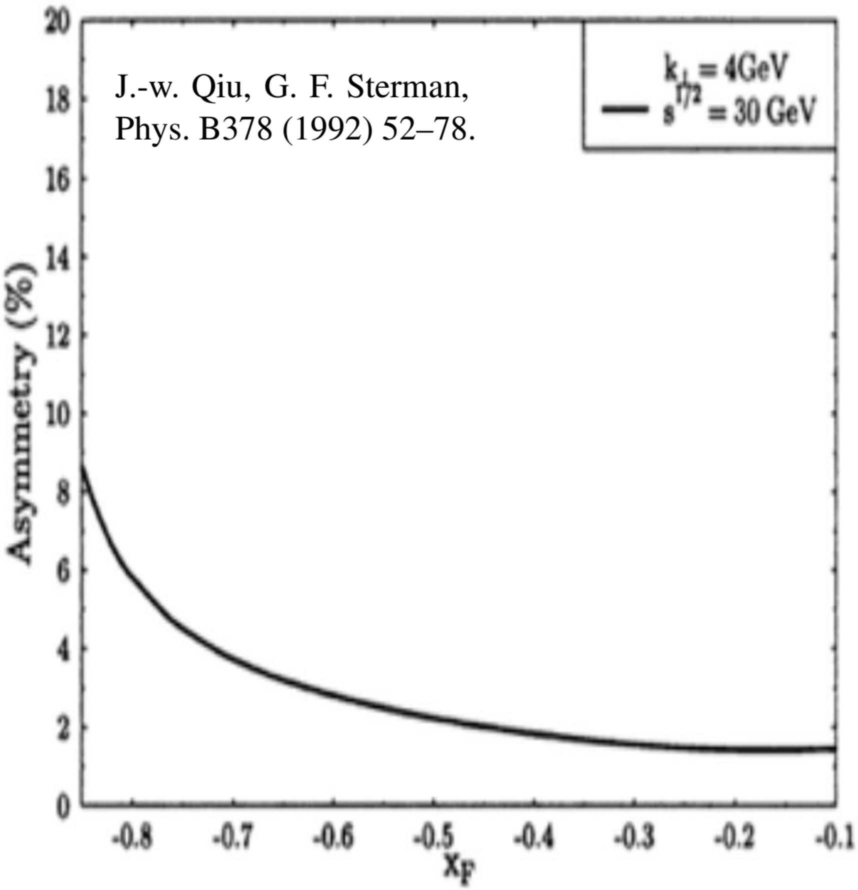
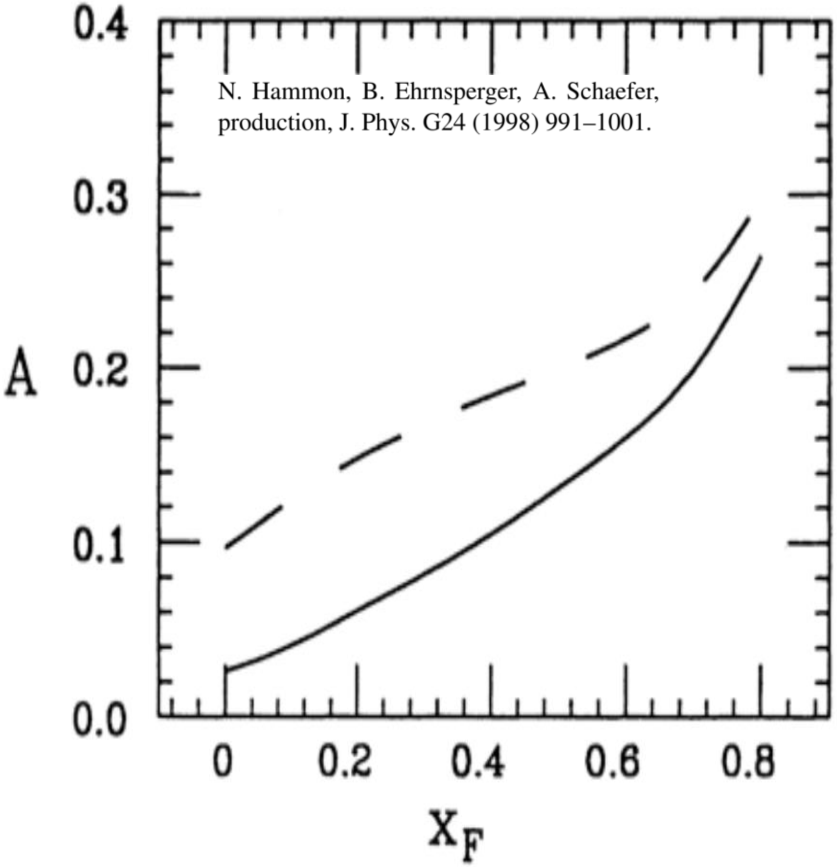


Figure 5: Measured cross section of prompt-photon production divided by the predicted one as a function of the x_T [3].

Expected asymmetries

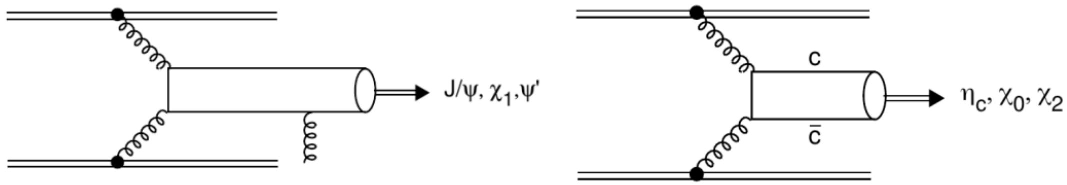




Charmonium production

Gluon fusion

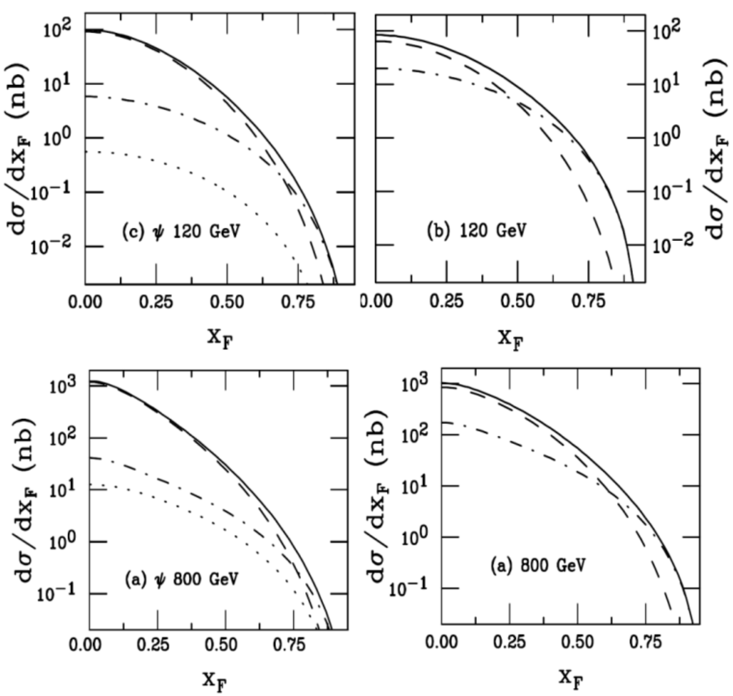
Charmonia production is sensitive to gluon distributions of colliding hadrons.

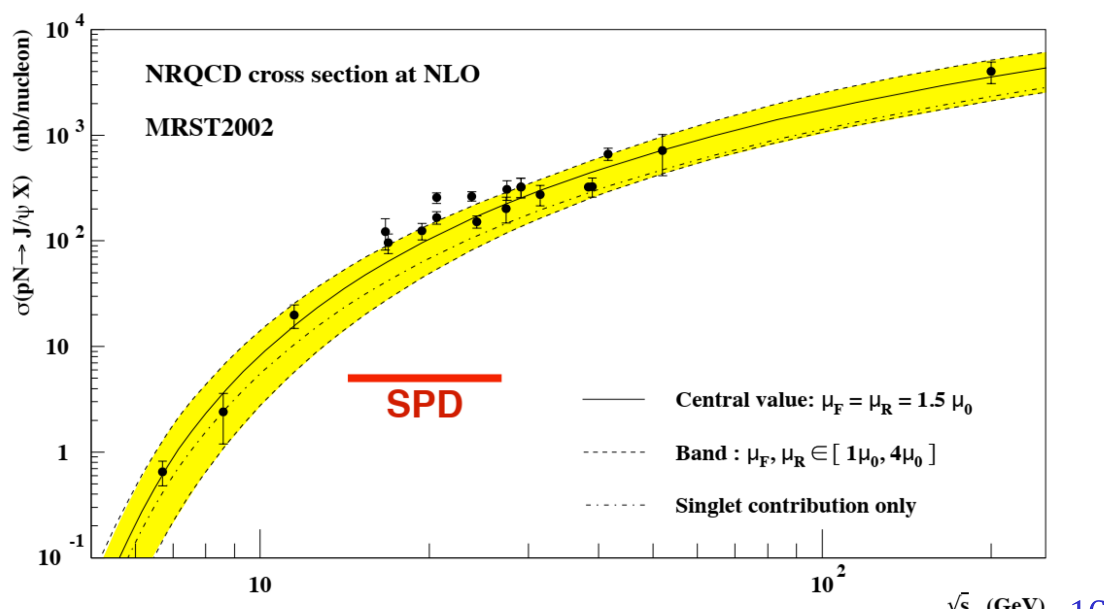


CS diagrams from Int. J Mod Phys A10:3043-3070 1995

Quark annihilation

NRQCD CEM

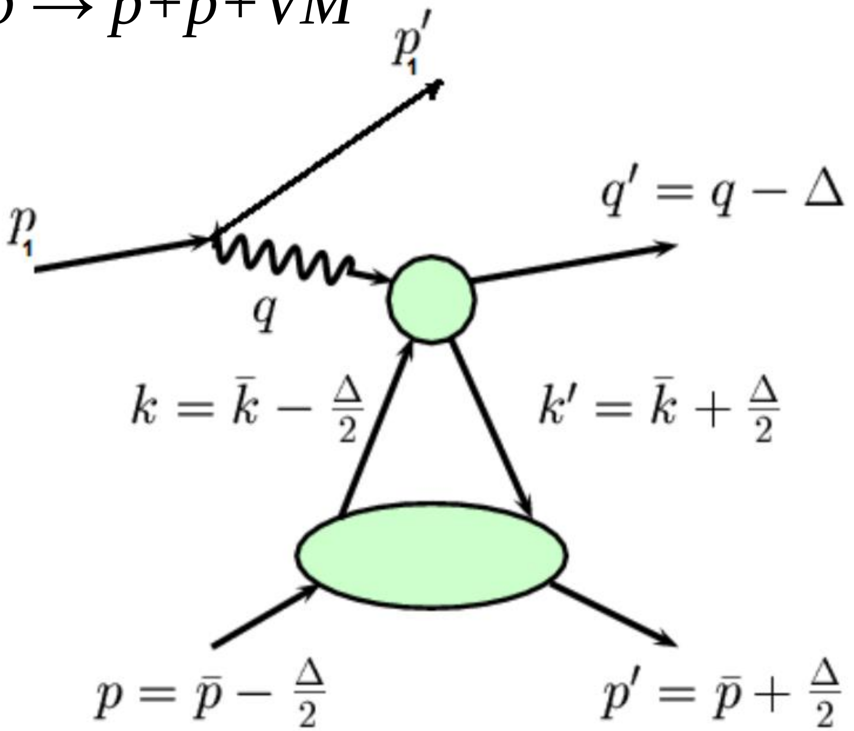




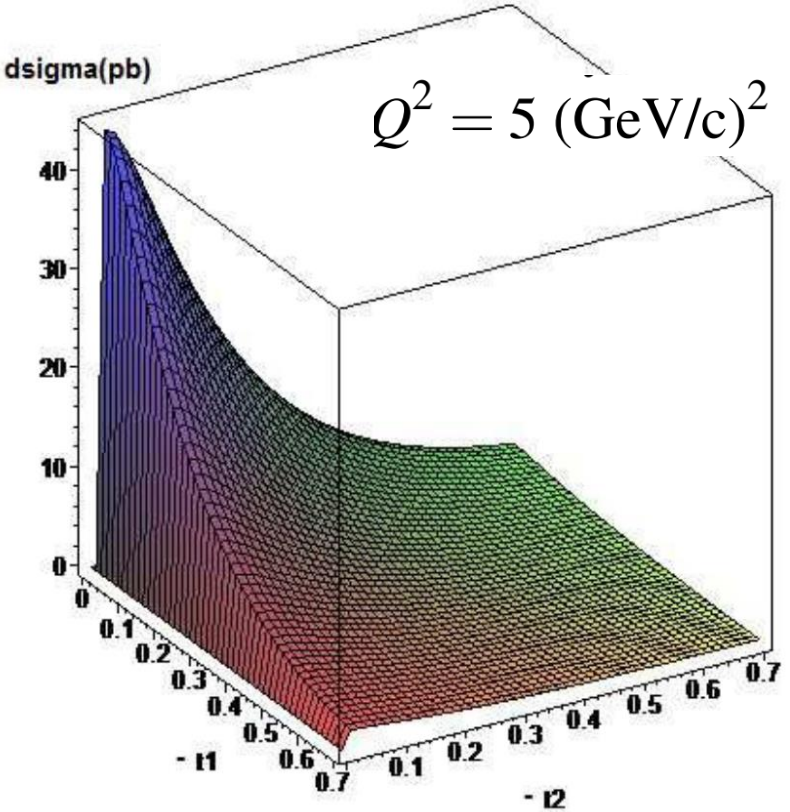
GPD through vector meson exclusive production

Exclusive DY

$p+p \rightarrow p+p+VM$

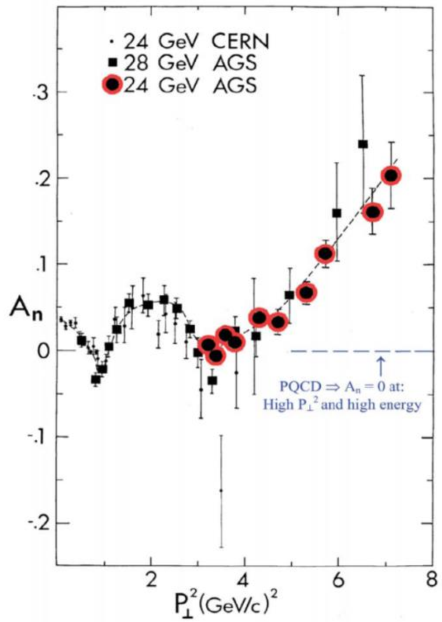


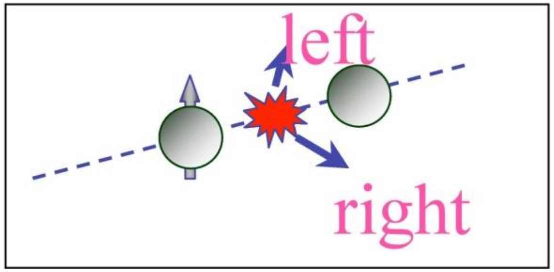
Vector meson production
via photoproduction mechanism or odderon exchange.



Asymmetries in high p_T hadron production

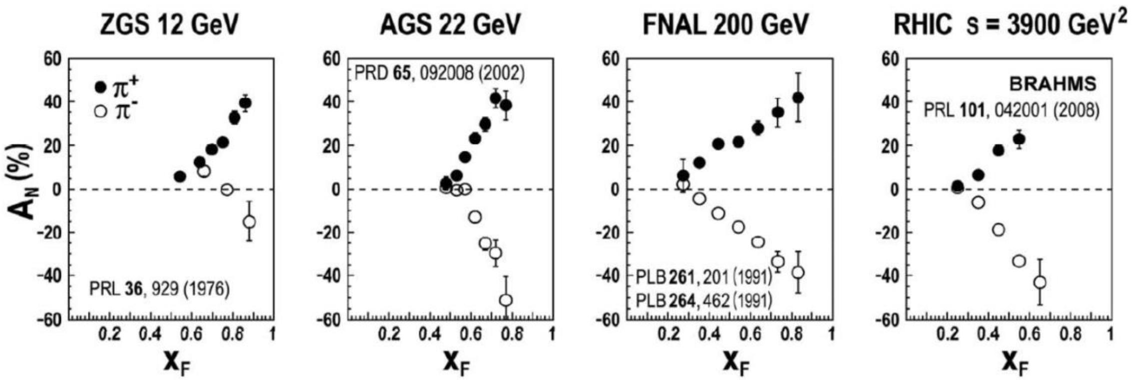
- Diquark properties;
- Confinement laws;
- Nature of the huge spin effects;
- Deuteron spin structure;
- Properties of the bare NΛ- and NK-interactions;
- Nature and properties of the cold super dense baryonic matter (CsDBM) (pA and AA);
- Dilepton production puzzle in np-interaction.

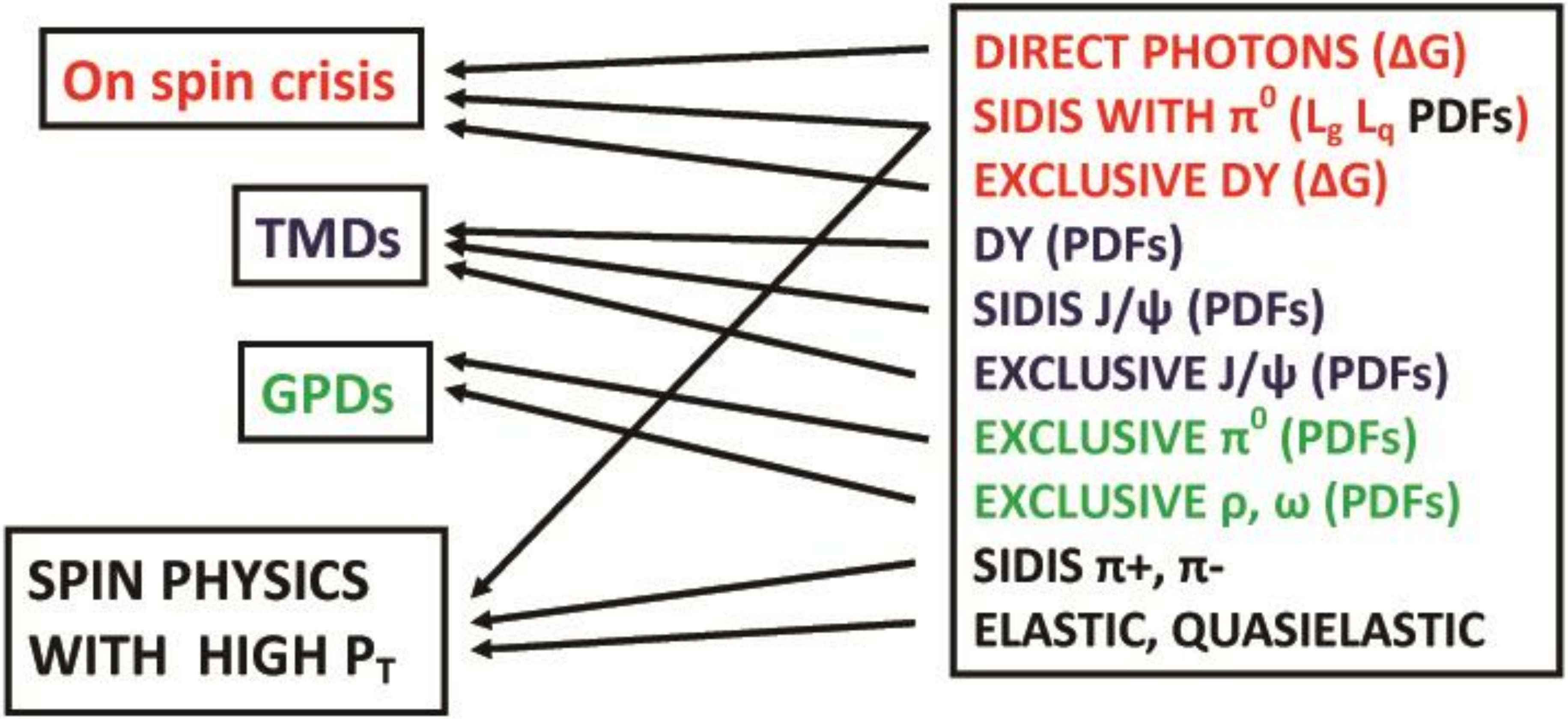




INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009

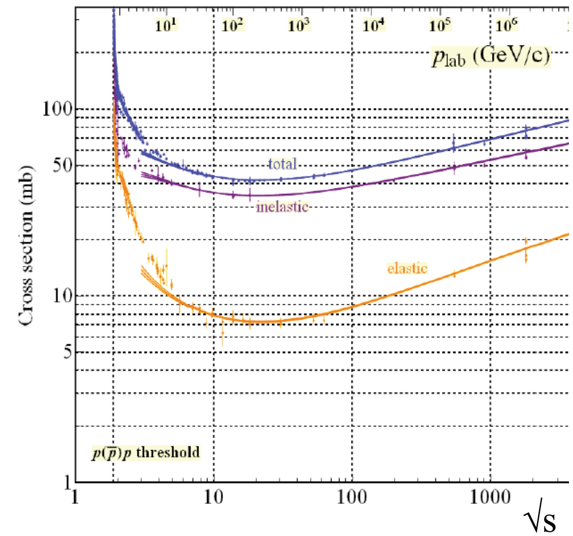


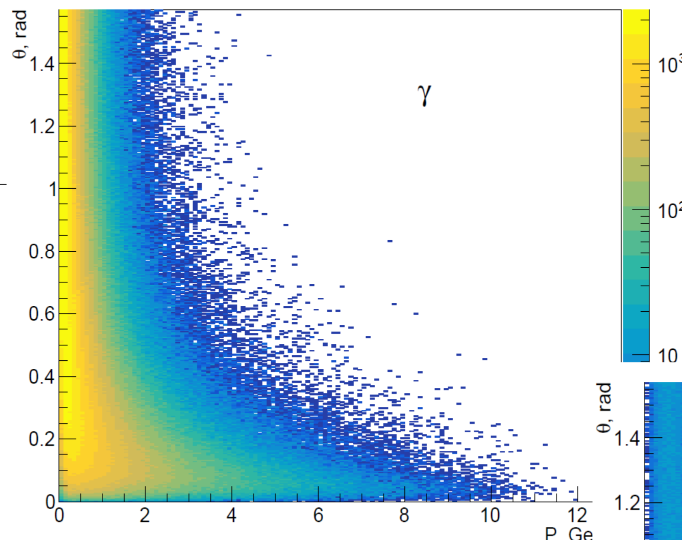

On spin crisis
TMDs
GPDs
SPIN PHYSICS WITH HIGH P_T
DIRECT PHOTONS (ΔG)
SIDIS WITH π^0 (L_g L_q PDFs)
EXCLUSIVE DY (ΔG)
DY (PDFs)
SIDIS J/ψ (PDFs)
EXCLUSIVE J/ψ (PDFs)
EXCLUSIVE π^0 (PDFs)
EXCLUSIVE ρ, ω (PDFs)
SIDIS π+, π-
ELASTIC, QUASIELASTIC

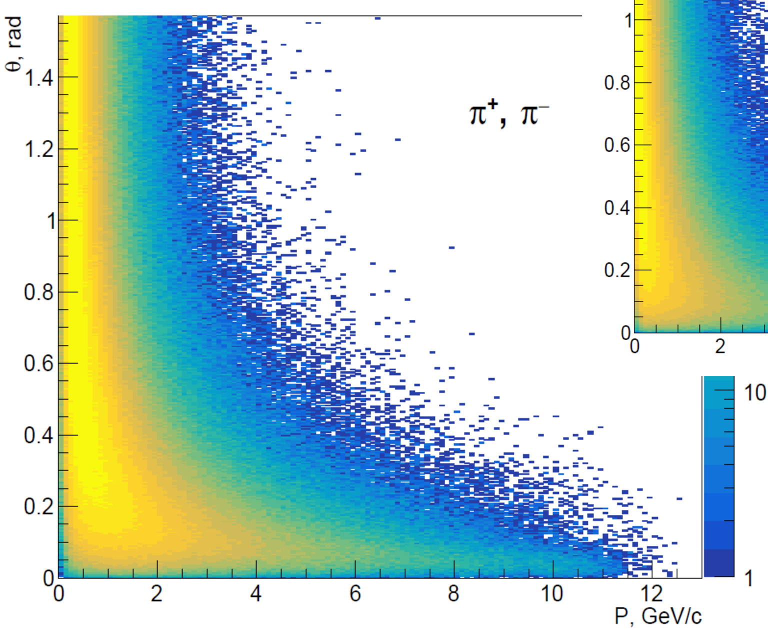
Minimum biased events

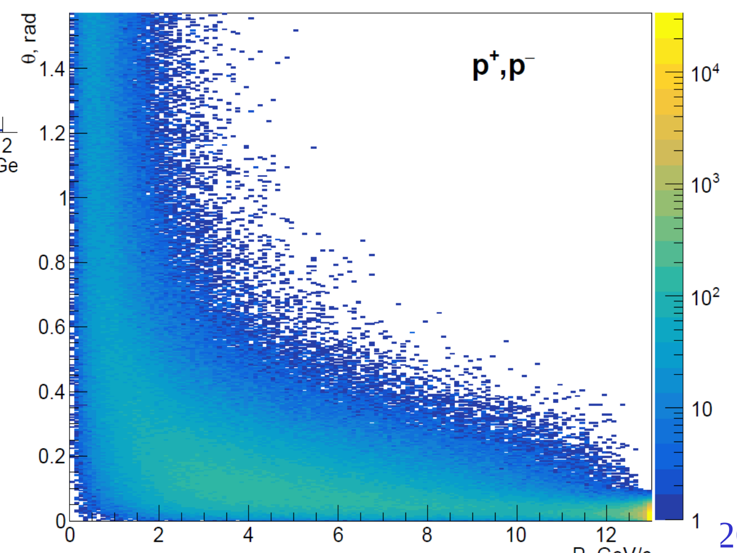
PYTHIA 6, $\sqrt{s_{pp}}$ = 26 GeV; 4 MHz event rate

- Average charged particles' multiplicity ~ 14
- Average neutral particles' multiplicity ~ 23









from A. Guskov

Local polarimetry

Asymmetry in inclusive production of charged particles

Single transverse spin asymmetry for very forward neutron production

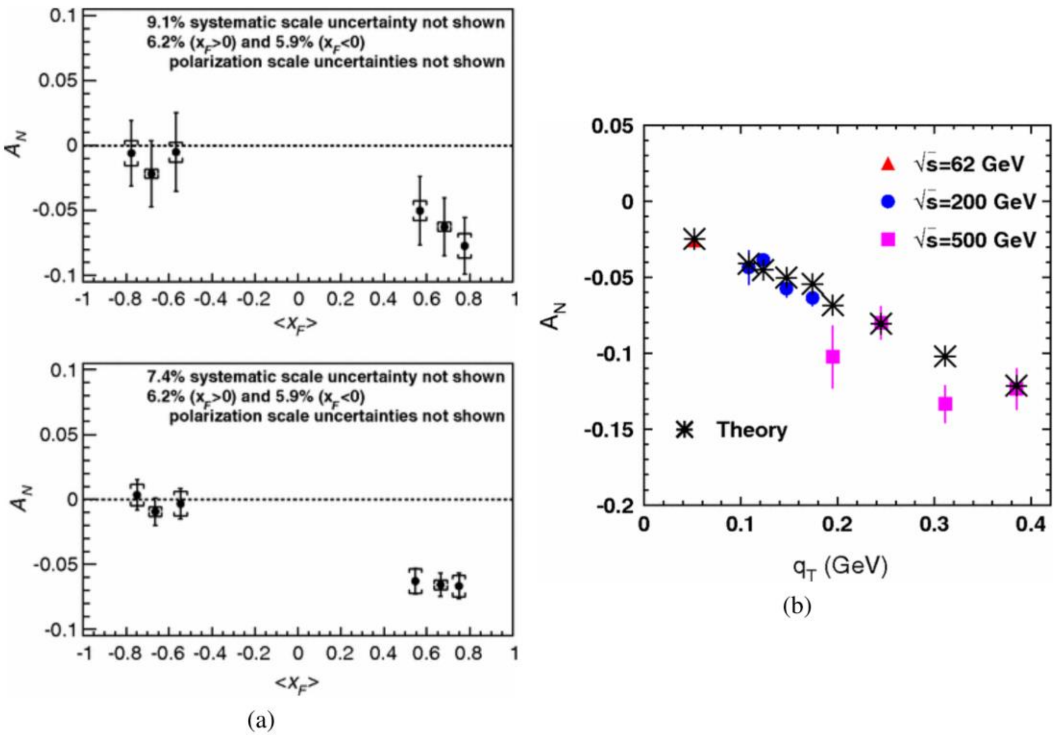
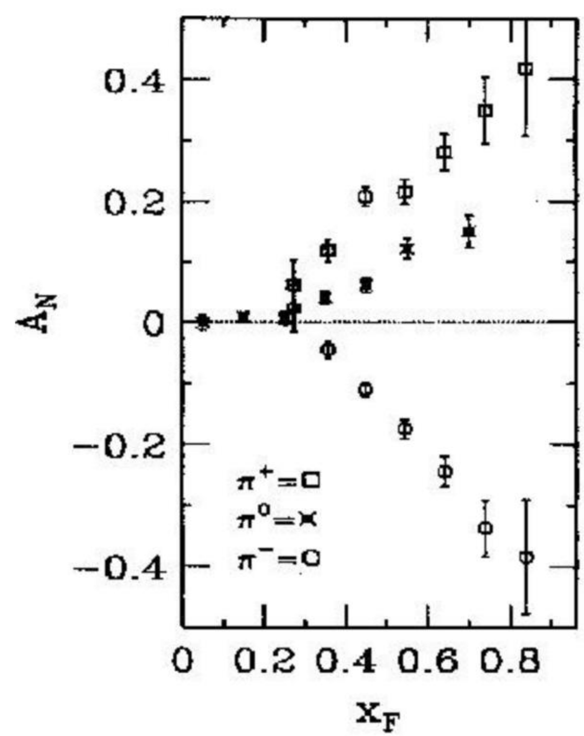
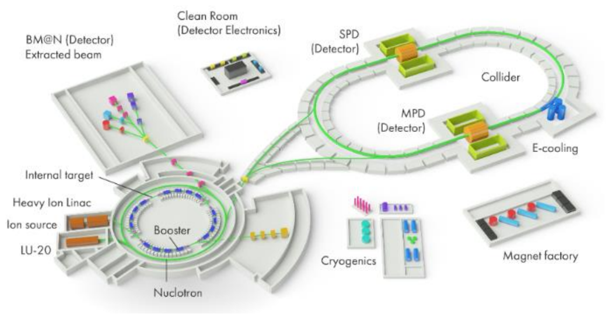


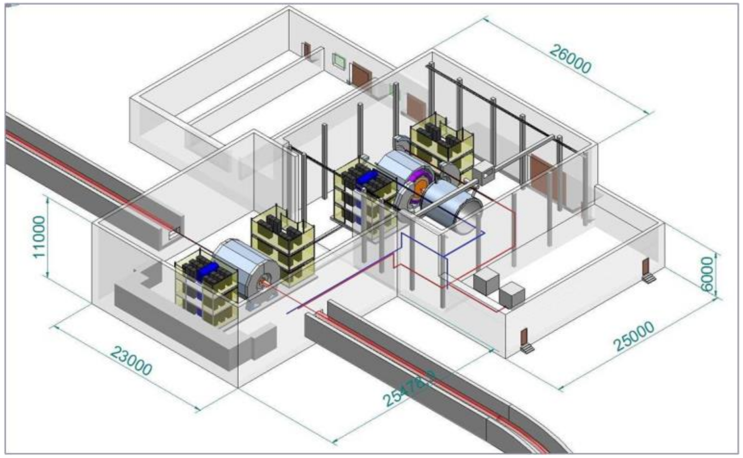
Figure 51: (a) The x_F dependence of A_N for neutron production in the (upper) ZDC trigger sample and for the (lower) ZDC⊗BBC trigger sample. (b) Single transverse spin asymmetry A_N in the reaction $pp \to nX$, measured at $\sqrt{s}$= 62, 200, 500 GeV measured at PHENIX. The asterisks show the result of the theoretical calculations [90].

Inclusive $pp \to \pi^0 X$ reaction



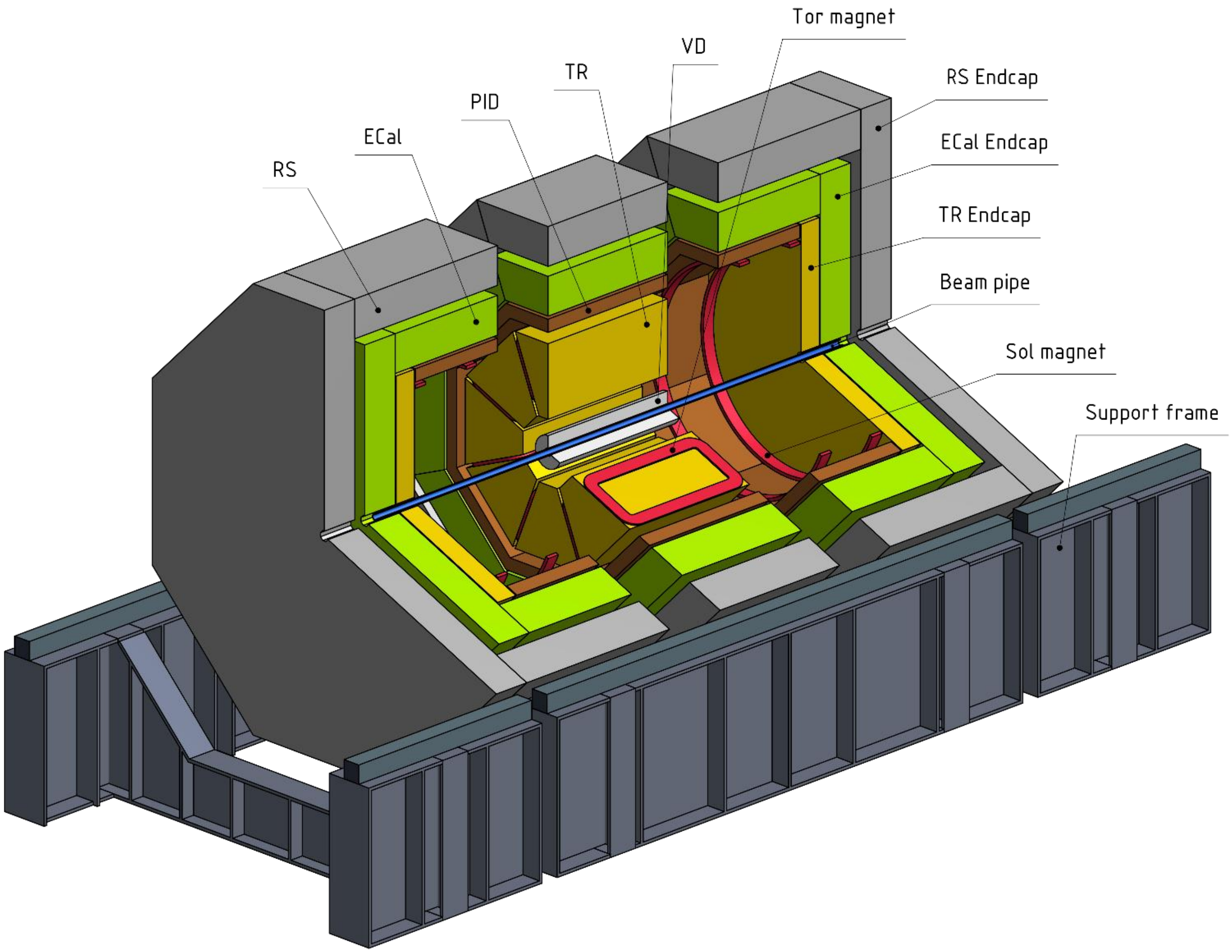
Requirements for the SPD



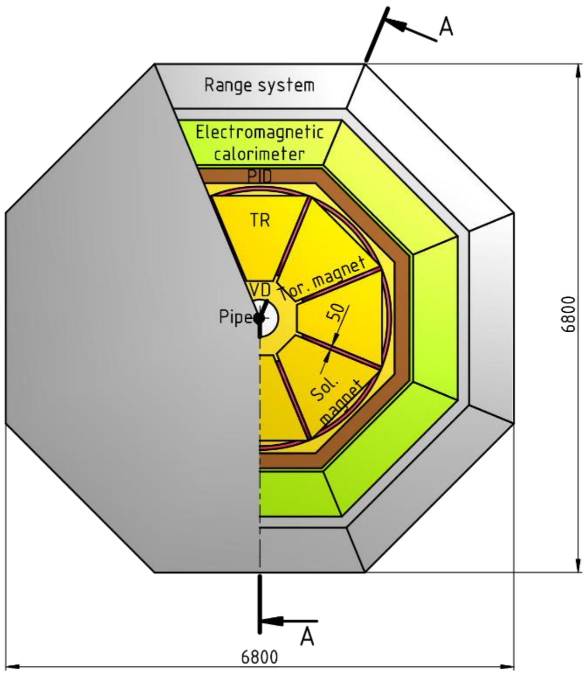


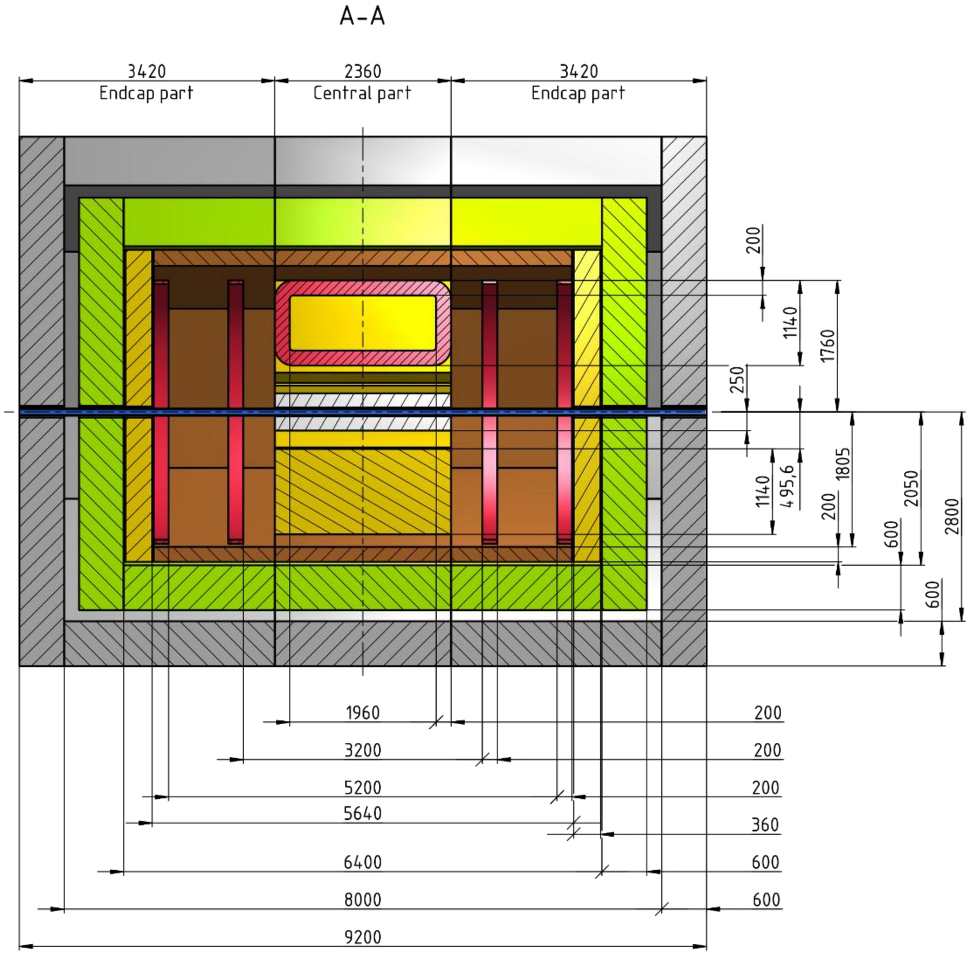
- close to 4π geometrical acceptance;
- high-precision (~50 µm) and fast vertex detector;
- high-precision (~100 µm) and fast tracker,
- good particle ID capabilities;
- efficient muon range system,
- good electromagnetic calorimeter,
- low material budget over the track paths,
- trigger and DAQ system able to cope with event rates at luminosity of 10^{32} $(cm.s)^{-1}$,
- modularity and easy access to the detector elements, that makes possible further reconfiguration and upgrade of the facility.

General view



Dimensions


A
Range system
Electromagnetic calorimeter
PID
TR
VD
Tor. magnet
50
Pipe
Sol. magnet
6800
A
6800


A-A
3420
Endcap part
2360
Central part
3420
Endcap part
200
1140
1760
250
1140
495,6
200
1805
2050
600
2800
600
1960
3200
5200
5640
6400
8000
9200
200
200
200
360
600
600

Hybrid magnetic system

½ model symmetry

$B^{(z)}(x,y,0)=0.$

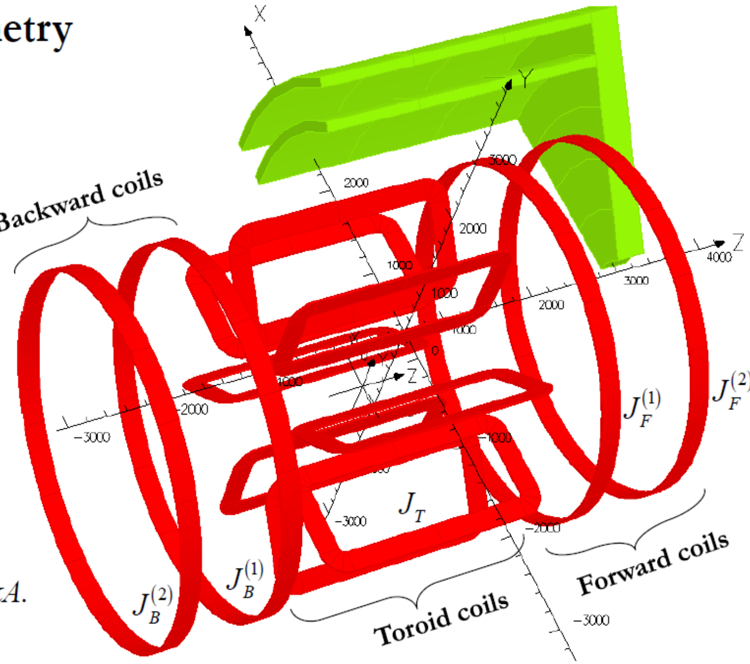
$J_T = 40\dfrac{A}{mm^2},$

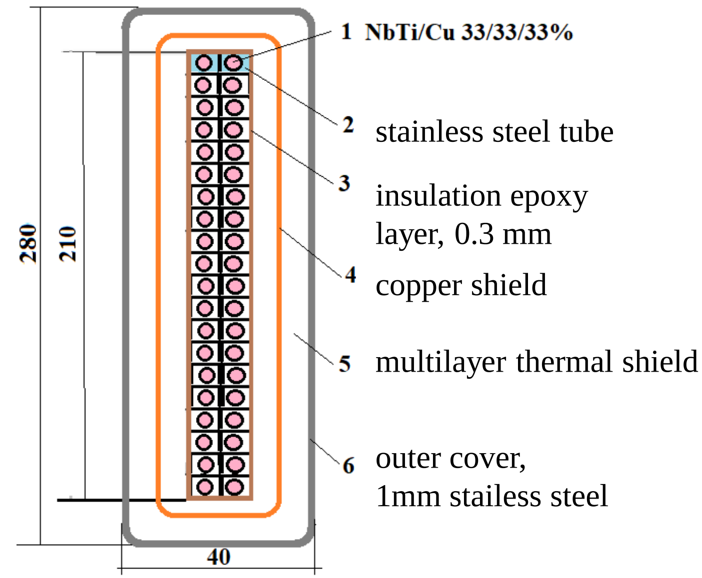
$J_{B\backslash F}^{(1,2)} = \mp 80\dfrac{A}{mm^2},$

$S = 200\times 20\,mm^2,$

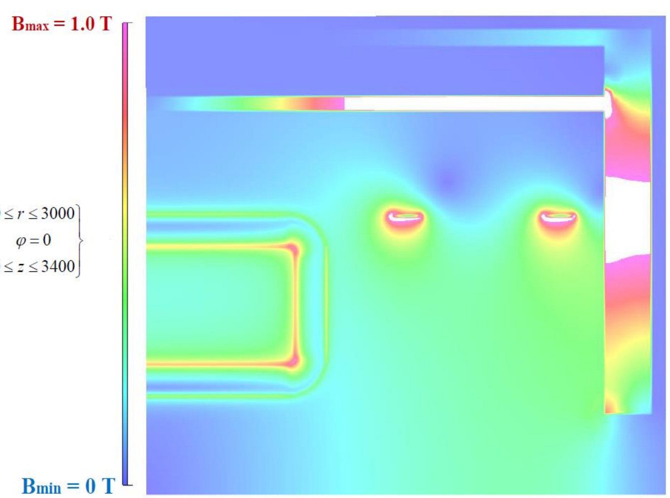
$I_T = J_T\cdot S = 160\,kA,$

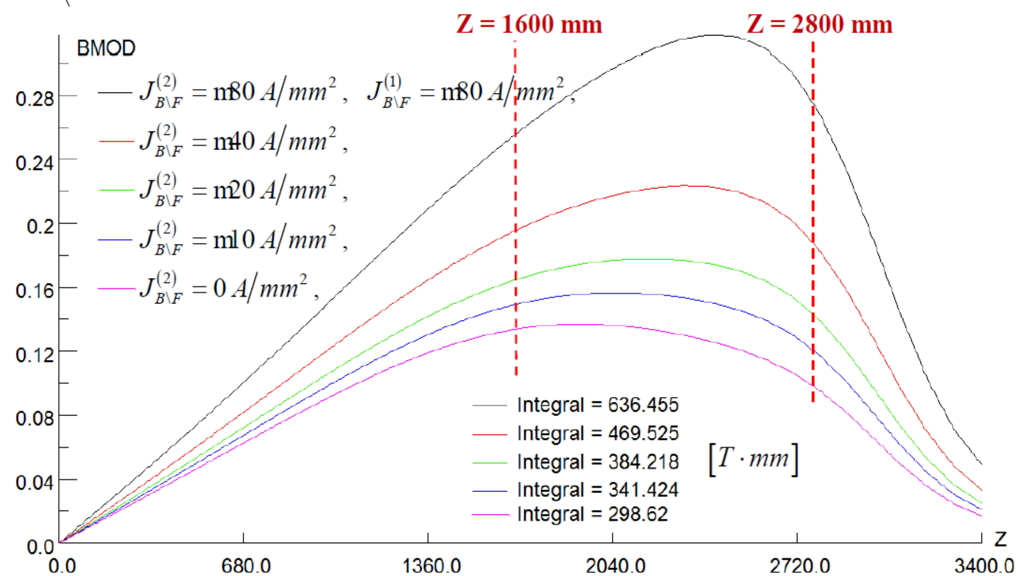
$I_{B\backslash F} = J_{B\backslash F}\cdot S = \mp 320\,kA.$



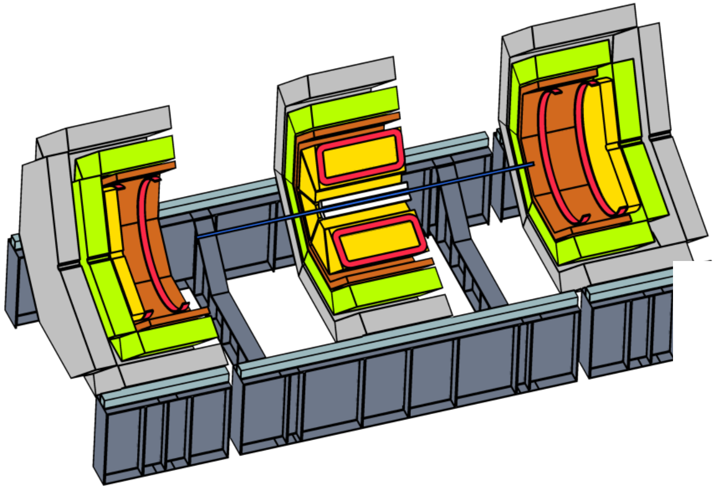


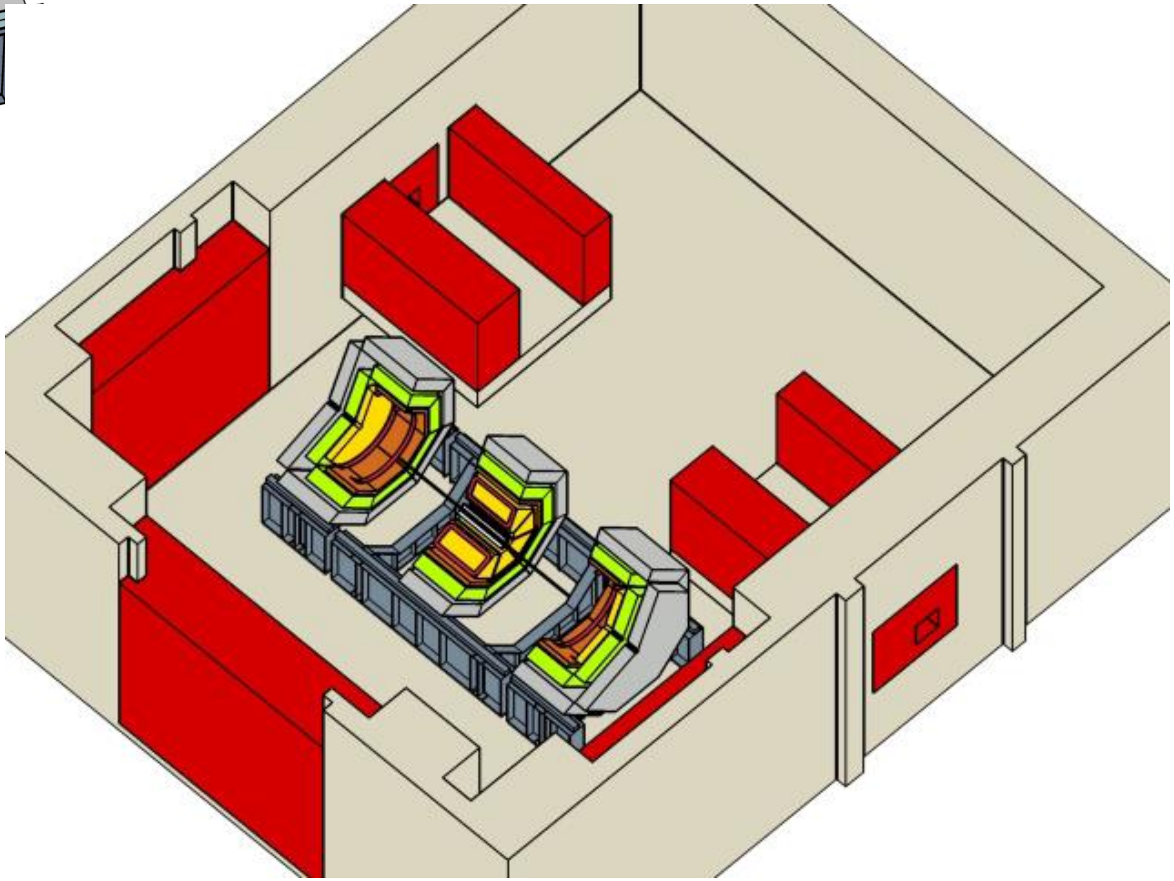
$\Omega = \left\{ (r,\varphi,z):\ \begin{matrix} 0\le r\le 3000 \\ \varphi = 0 \\ 0\le z\le 3400 \end{matrix} \right\}$



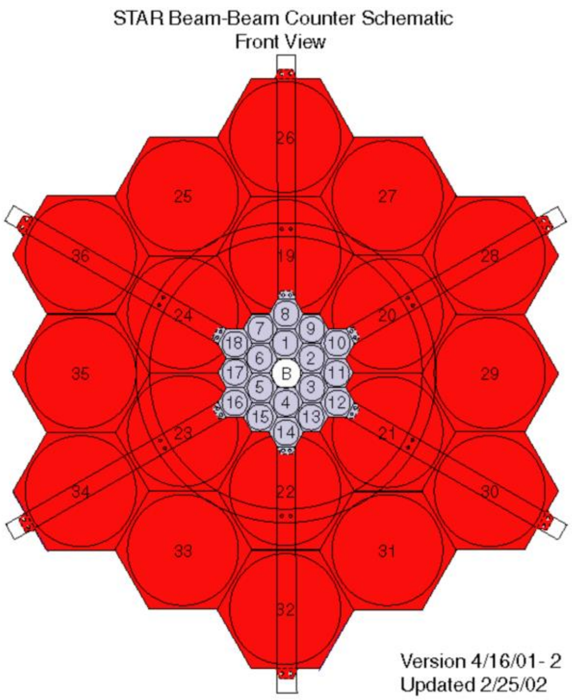


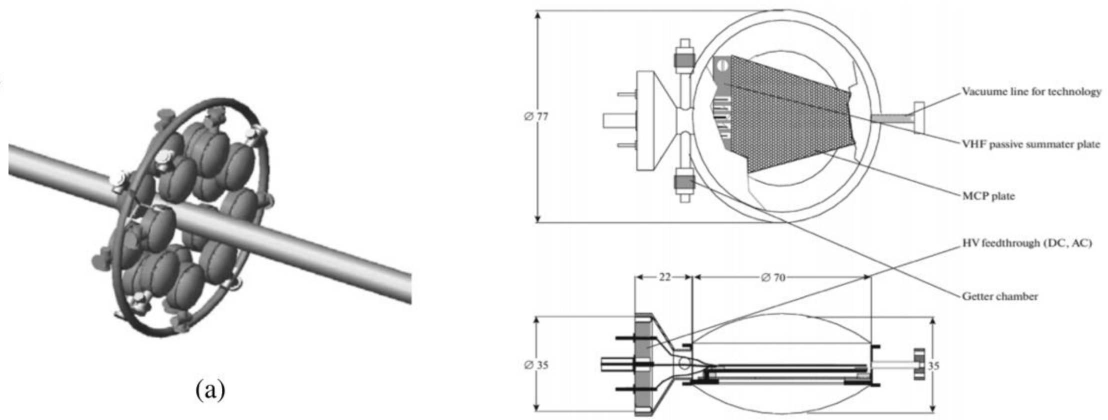
Reconfigurable design





Beam-beam interaction and t0 counters



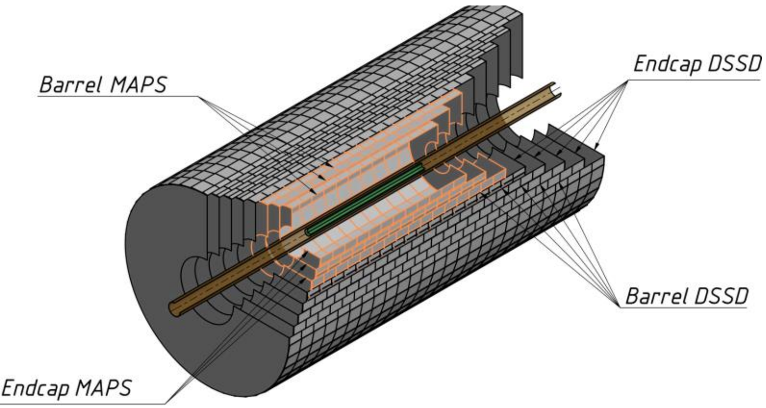


(a)

(b)

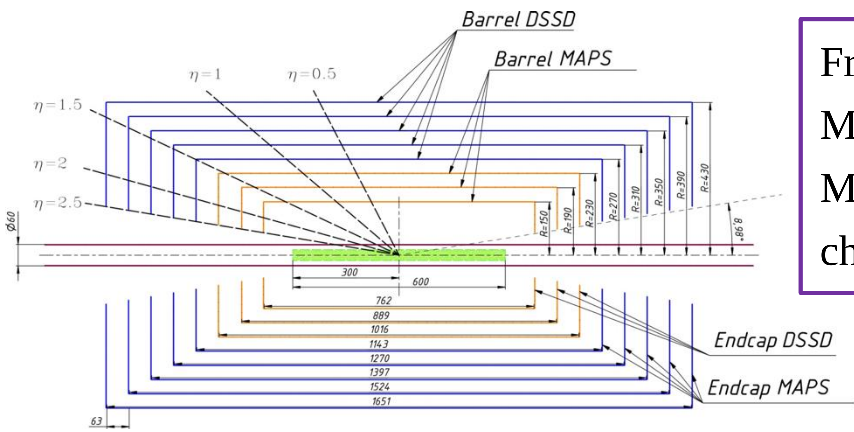
Figure 48: (a) The conceptual general layout of timing and multiplicity detector formed by 16 sectors of MCP placed inside the independent thin wall Ti vacuum chambers around the beam line. (b) General design of the MCP prototype detector embedded into a thin-wall (200 μm) Ti lens-type chamber.

Vertex detector / Inner tracker

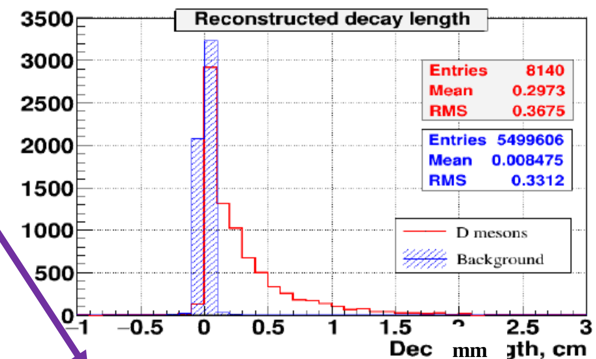


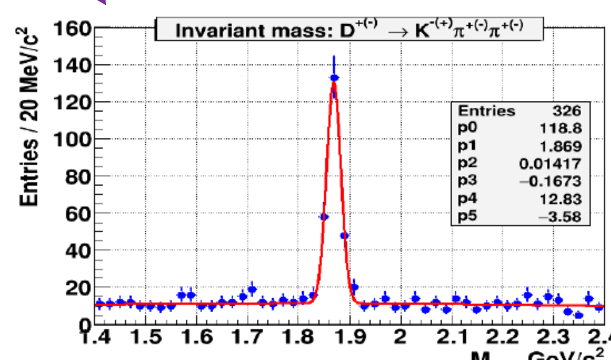
Silicon Vertex Detector

- Silicon vertex detector around the beam pipe;
- Several layers of double sided silicon strips and MAPS;
- Optimized number of layers w.r.t. material budget;
- Goal: few tens of μm resolution for the vertex reconstruction → detection of particles with open charm and rejection of (π) decay muons.



From A. Zinchenko, MPD ITS with MAPS → open charm registration

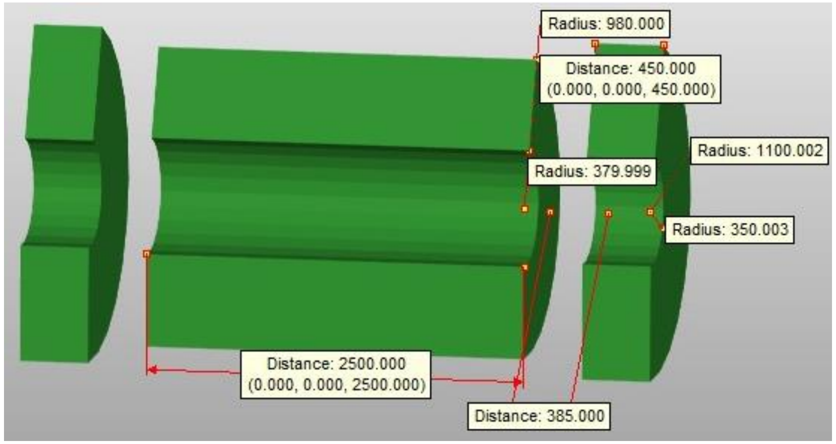




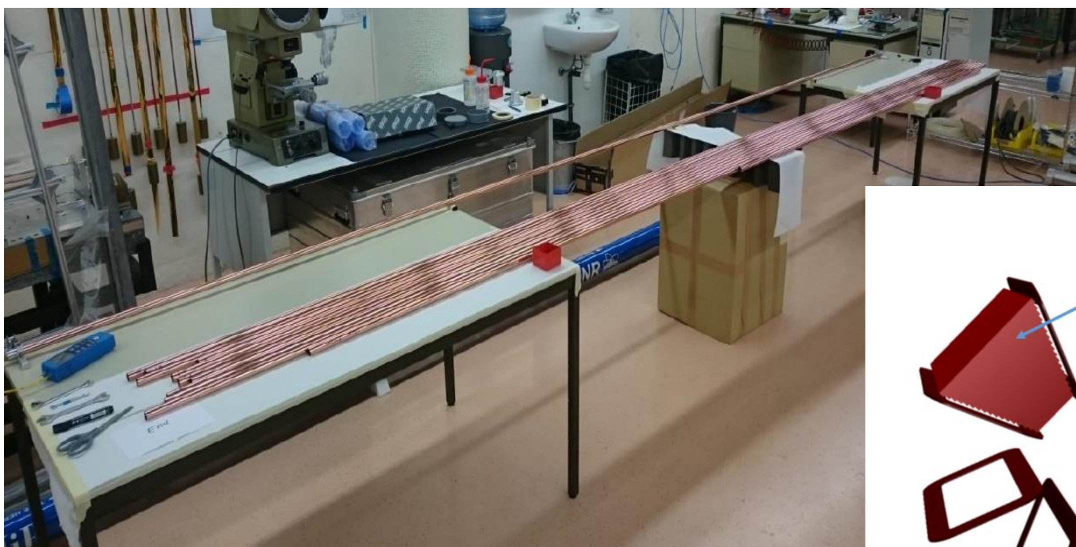
DSSD: 19.5 m^2

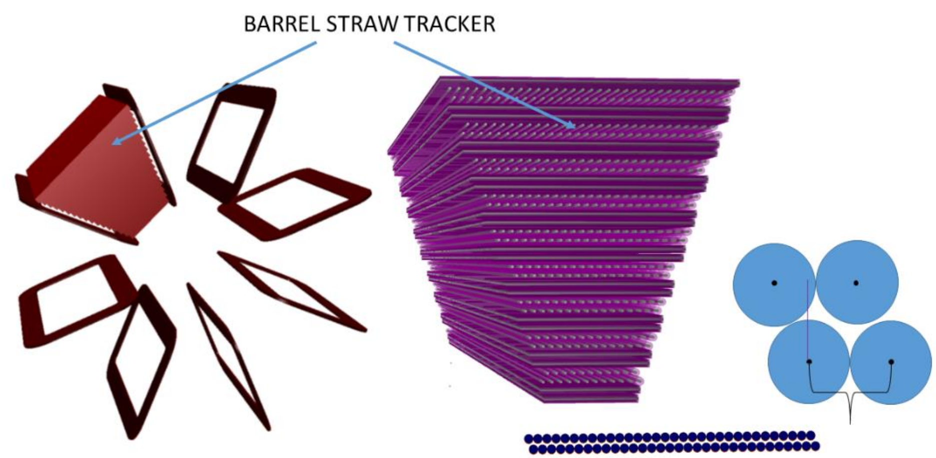
MAPS: 3.5 m^2

Central tracker: straw tubes

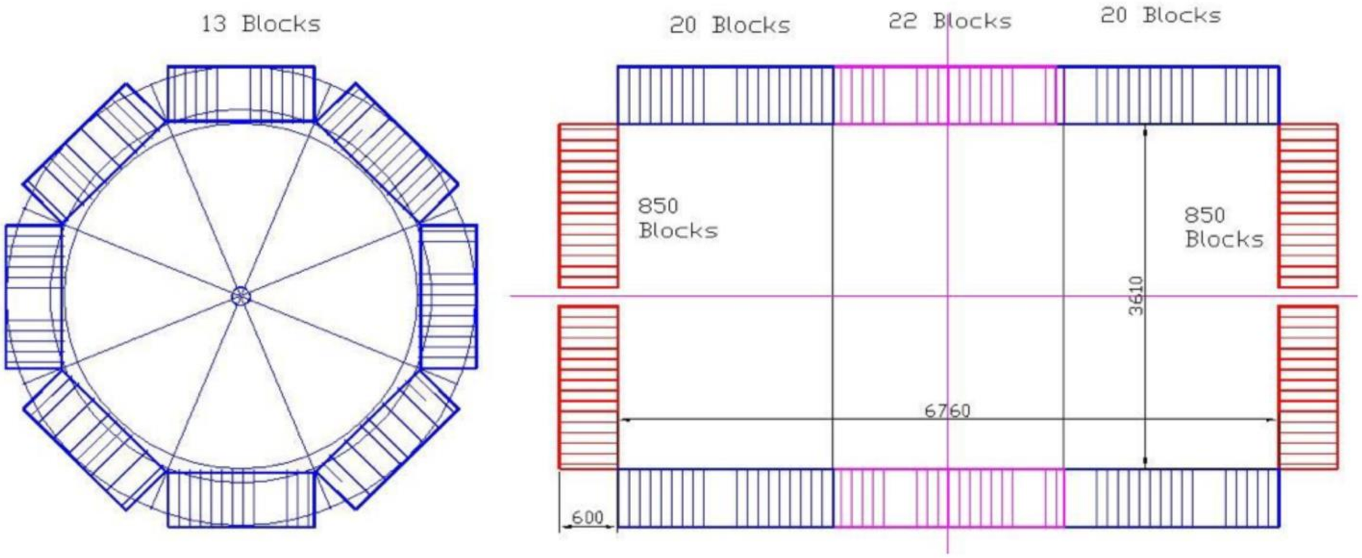


- Minimum material on the particle tracks (X_0 ~ 0.1);
- Time (~ 100 ns) and spatial resolution (~100 µm);
- Expected particle rates (DAQ rates) ~ MHz;
- Technology developed also in JINR, production workshops available





Electromagnetic calorimeter



~6500 modules

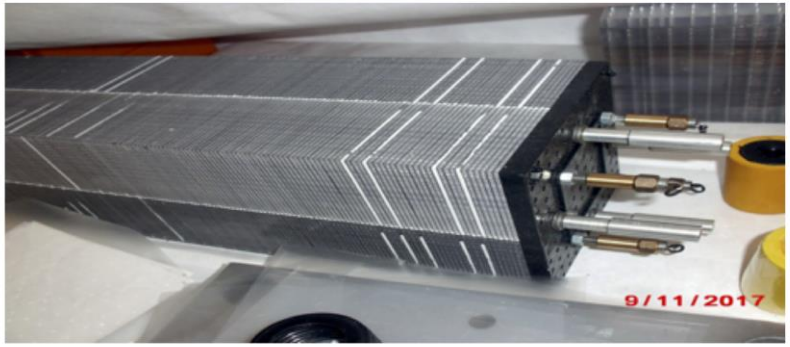
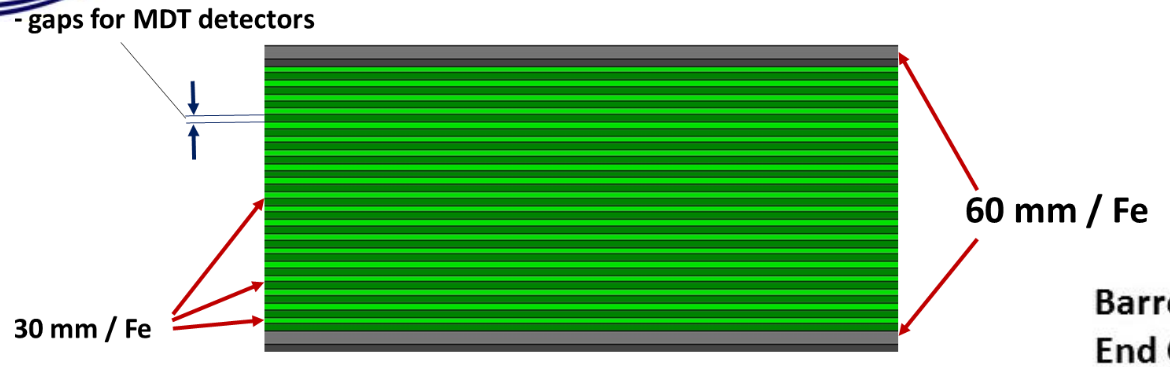


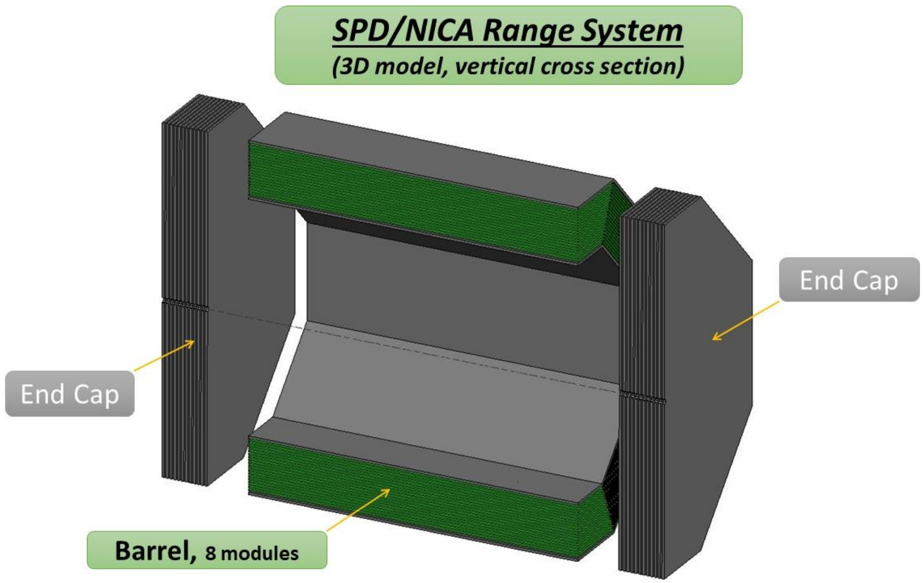
Figure 33: Two by two modules of the KOPIO sampling calorimeter assembled in the single block with 320 layers of lead and scintillator of 0.3 mm and 1.5 mm thick, respectively.

- 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 <10.0%/√E (GeV) and energy threshold below 100 MeV.
- Design ("shashlik") similar of that for KOPIO calorimeter, G. S. Atoian, V. V. Issakov, O. V. Karavichev, T. L. Karavicheva, A. A. Poblaguev, M. E. Zeller, Development of Shashlyk calorimeter for KOPIO, Nucl. Instrum. Meth. A531 (2004) 467–480.
- Crystal variant is being considered, too.

Range system



Barrel/Fe: 60+15x30+60 mm (3 λ i);
End Caps/Fe : 9x60 mm (2.8 λ i);
Air gaps = 35 mm; **L /barrel** = 8000 mm;
W = 1224.5 ton
Version : 09.2018



- It should provide good (>95%) muon identification for momenta above 1 GeV.
- Combination of responses from the ECal and RS could give additional lever for regecting of pions and protons in a wide energy range.
- The RS also provides additional coordinate measurement.

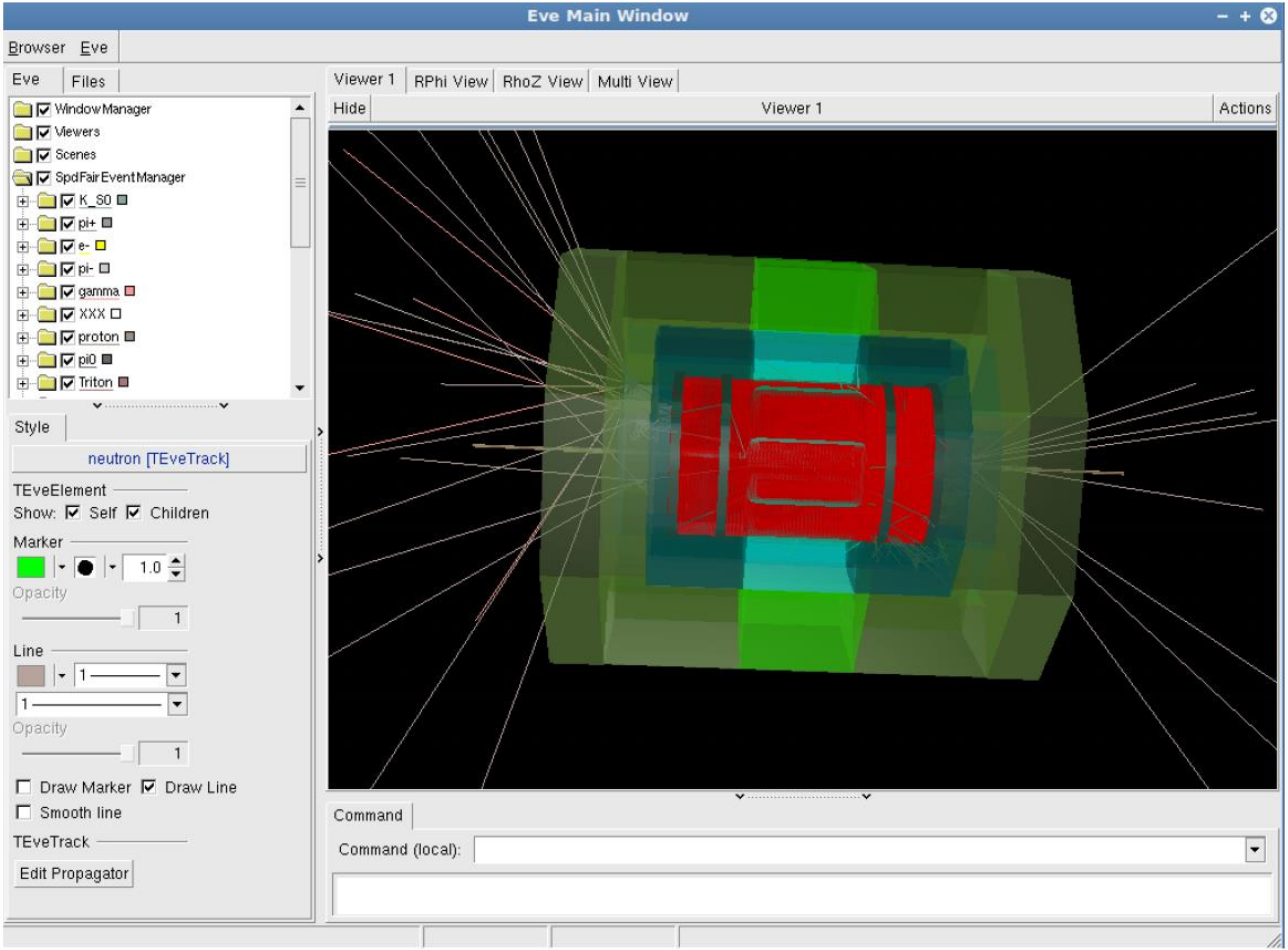
Our design will follow closely the design of the PANDA experiment range system (at FAIR, GSI) being developed now at the DLNP of JINR

Figure 43: Demonstration of PID abilities – (a) proton vs. muon, and (b) proton vs. neutron.

DAQ

- The SPD DAQ may be developed *a la* FPGA-based DAQ of the COMPASS experiment;
- Event rate ~3.0 MHz (at $L=10^{32}$ $cm^{-2}s^{-1}$, $\sqrt{s}=27$ GeV);
- Rough preliminary estimation of the total data flux from the detectors (Si tracker + straw tracker + PID + ECal + range system): 10-20 GBytes/s (no detailed simulation results available yet);
- Triggered or trigger-less DAQ: to be decided.

Software and computing



Project status and roadmap

Start of the SPD project

- **Letter of Intent** presented at the JINR PAC in summer 2014, where:
  - the physics program of the experiment was developed;
  - requirements to NICA polarized beams were formulated;
  - desired detector characteristics and sketch of the facility were given;
- A few presentation at international conferences about the physics potential and program of the SPD were given;
- Several workshops on spin physics at NICA were organized:
  - NICA-SPIN-2013, Дубна, 17-19.03.2013
  - SPIN-Praha-2013, 7-13.07.2013
  - NICA-SPIN-2014, Praha, 11-16.02.2014
  - SPIN-Praha-2015, 26-31.07.2015
  - DSPIN2013, DSPIN2015, DSPIN2017

arXiv: 1408.3959

Nec sine te, nec tecum vivere possum. (Ovid)*

Spin Physics Experiments at NICA-SPD with polarized proton and deuteron beams.

Compiled by the Drafting Committee:
I.A. Savin, A.V. Efremov, D.V. Peshekhonov, A.D. Kovalenko, O.V.Teryaev, O.Yu. Shevchenko, A.P. Nagajcev, A.V. Guskov, V.V. Kukhtin, N.D. Topilin.

(Letter of Intent presented at the meeting of the JINR Program Advisory Committee (PAC) for Particle Physics on 25–26 June 2014.)

In 2017 a new stage of the project started:
From LoI to CDR (Conceptual Design Report)

op on Spin Physics
a-2018)

http://SPIN-Praha-2018

This International Workshop on Spin Physics Experiments at NICA (SPIN-Praha-2018) is the next in the series of meetings on problems of symmetries and polarization phenomena in Particle and Nuclear Physics and Astrophysics related to the particles' spin. They have begun with the first meeting of this series at the Joint Institute for Nuclear Research, Dubna, in 1975, and continued on a regular basis from 1976 on in Czech Republic. Links to the Web sites of the previous meetings can be found at http://spd.jinr.ru/doku.php?id=conferences.

Status

- Simplified detector sketch and simulations of basic physics processes (Oct. 2017- end of 2018) **ONGOING**;
- Development of a simplified design of the detector and costing **ONGOING**;
- Negotiations for an international collaboration and sharing of responsibilities for the design and construction of the facility **ONGOING** :
  - INFN section of Turin and University of Turin;
  - Charles University, Prague;
  - Technical University, Prague
  - Tomsk State University;
  - Tomsk Polytechnic University;
  - Institute of Applied Physics of the Belarus Academy of Sciences;
  - Gomel State Technical University, Belarus;
  - Institute for High Energy Physics, Protvino;
  - Institute of Nuclear Physics of the Moscow State University;
  - Institute for Nuclear Research of the RAS, Troitsk;
  - Lebedev Physics Institute of the RAS, Moscow;
  - Institute for Theoretical and Experimental Physics, Moscow;
  - St. Petersburg Nuclear Physics Institute, Gatchina;
  - St. Petersburg State University;
  - St. Petersburg Polytechnic University

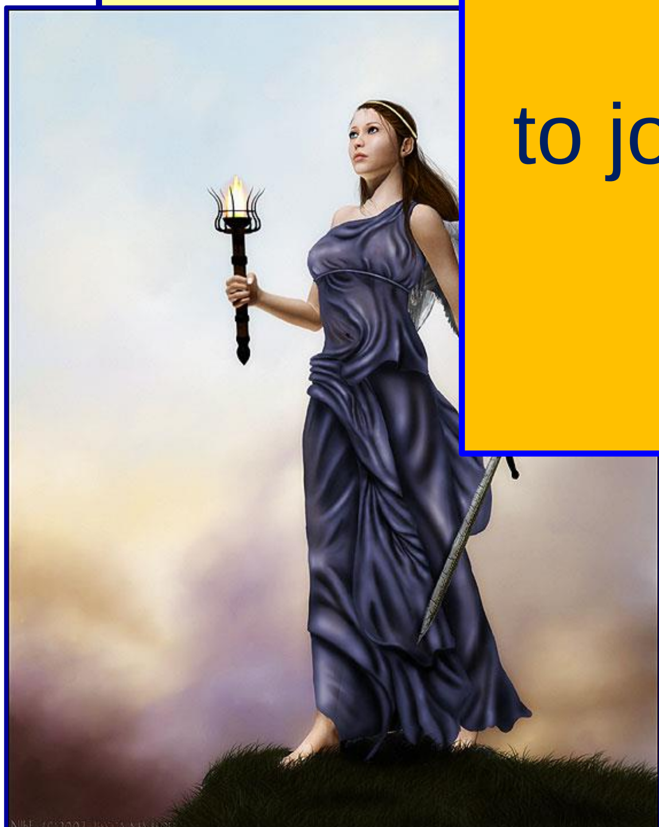
Protocols for joint research within the SPD project signed.

Bilateral agreements on NICA exist.

Roadmap

- JINR project for the SPD design (Jan. 2019);
- Setting up of the collaboration, MoU (2019);
- Preparation of the Conceptual Design Report (2019);
- Preparation of the Technical Design Report (including prototyping):
  - first stage (2020 – 2022);
  - second stage (2023);
- Construction of the detector (2022-2025);
- First measurements – 2025…

SPD/NICA will provide a unique opportunity *not available at other facilities* to study all of the PDFs in one experiment and obtain comprehensive information on the nucleon spin structure ... level ... inties



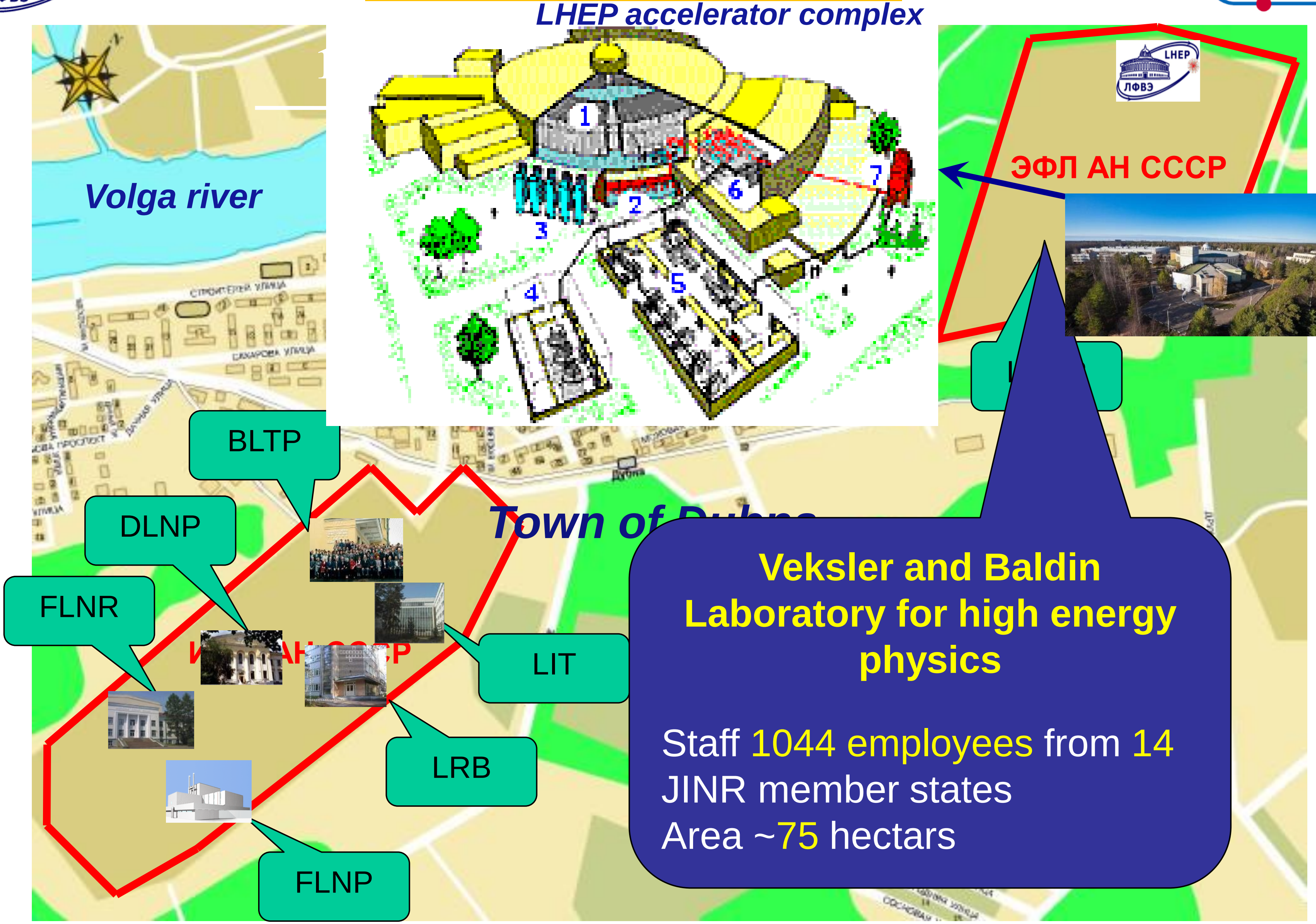
You are welcome
to join the SPD/NICA project!

Web site: *spd.jinr.ru*.

Contact person: Roumen Tsenov (*tsenov@jinr.ru*)

Back-up

JINR history



Veksler and Baldin Laboratory for high energy physics

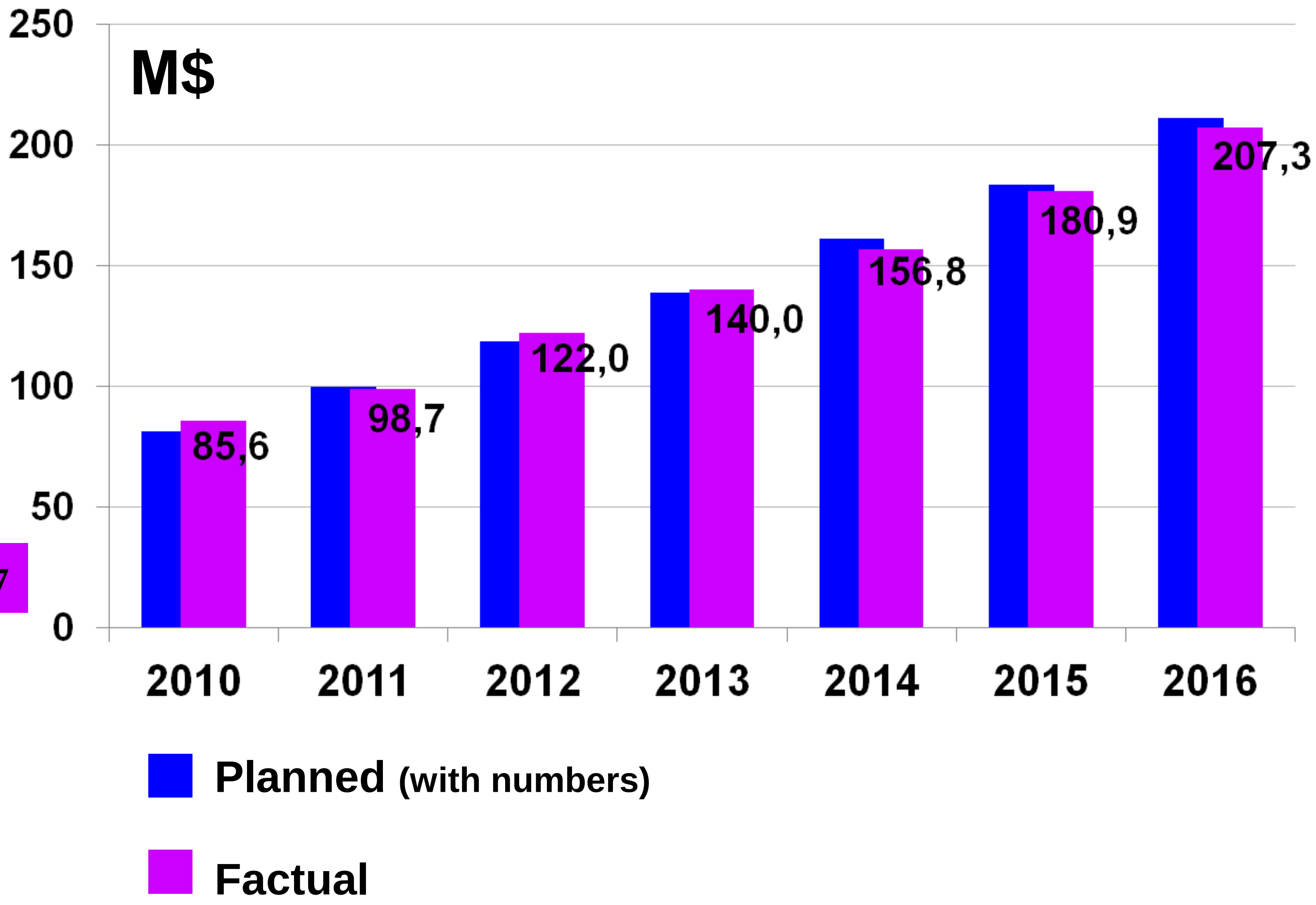
Staff 1044 employees from 14 JINR member states
Area ~75 hectars

Megaproject NICA

The NICA project which is under implementation at the Joint Institute for Nuclear Research underlies the "NICA Complex" megaproject. At present, JINR has 18 full member states from Europe, Asia and Latin America. Thus, the NICA project approved by the JINR international bodies is in fact already an international project. 30 countries are interested and taking part in its implementation. Besides the Member States, agreements are signed with Germany, China, the US, CERN and SAR.

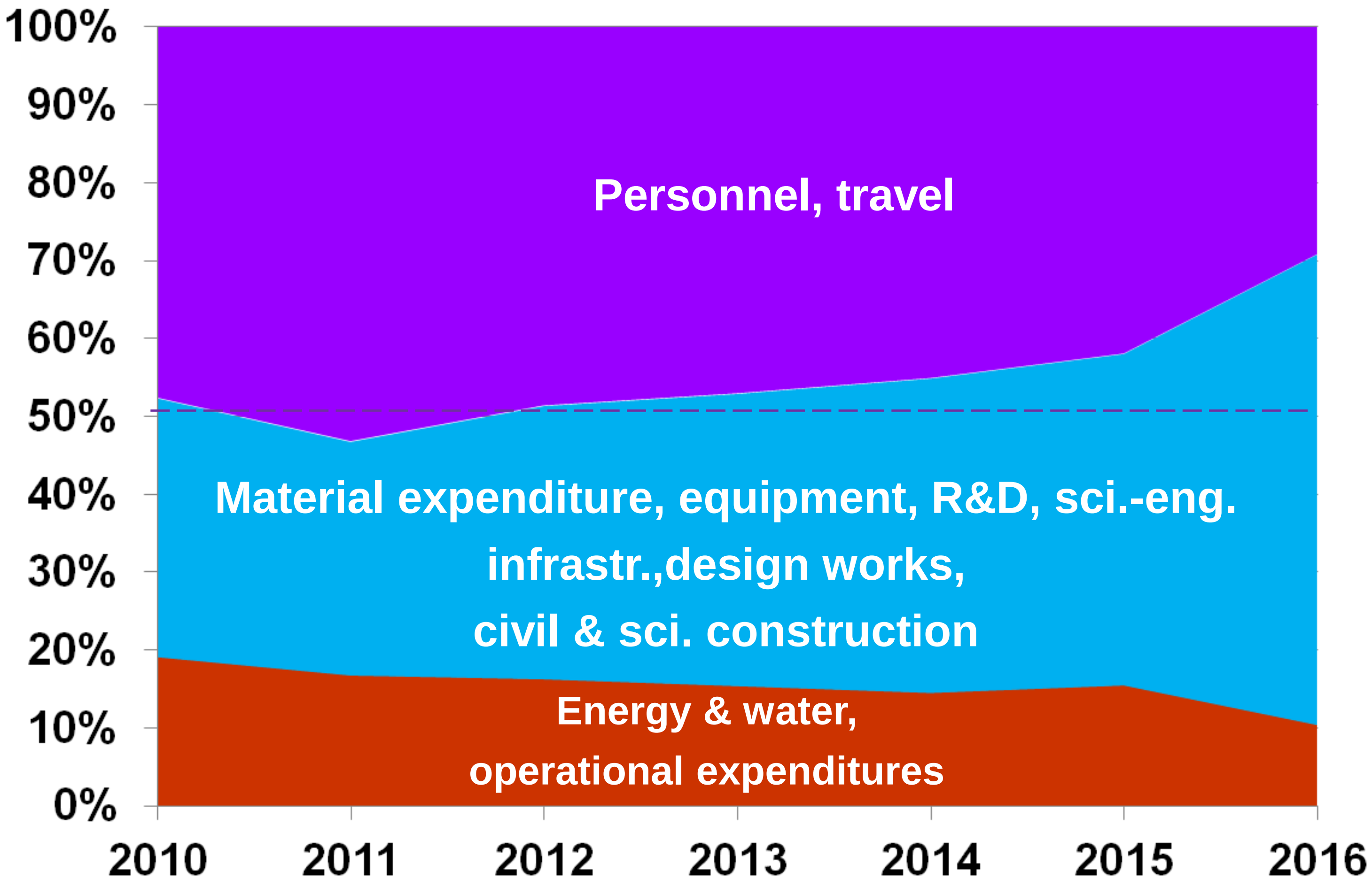
Australia
Azerbaijan
Armenia
Belarus
Bulgaria
Brazil
Vietnam
Germany
Greece
Georgia
India
Italy
Kazakhstan
China
DPRK
Moldova
Mongolia
Poland
Romania
Russia
Serbia
Slovakia
USA
Czech Republic
Ukraine
Uzbekistan
France
SAR
Japan
CERN

JINR budget

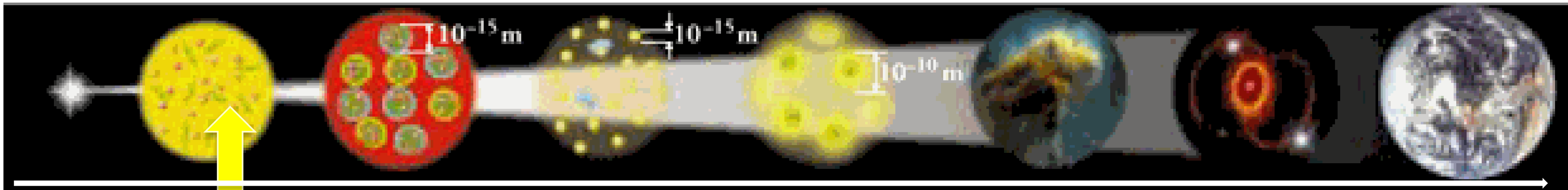


2009: **68,7**

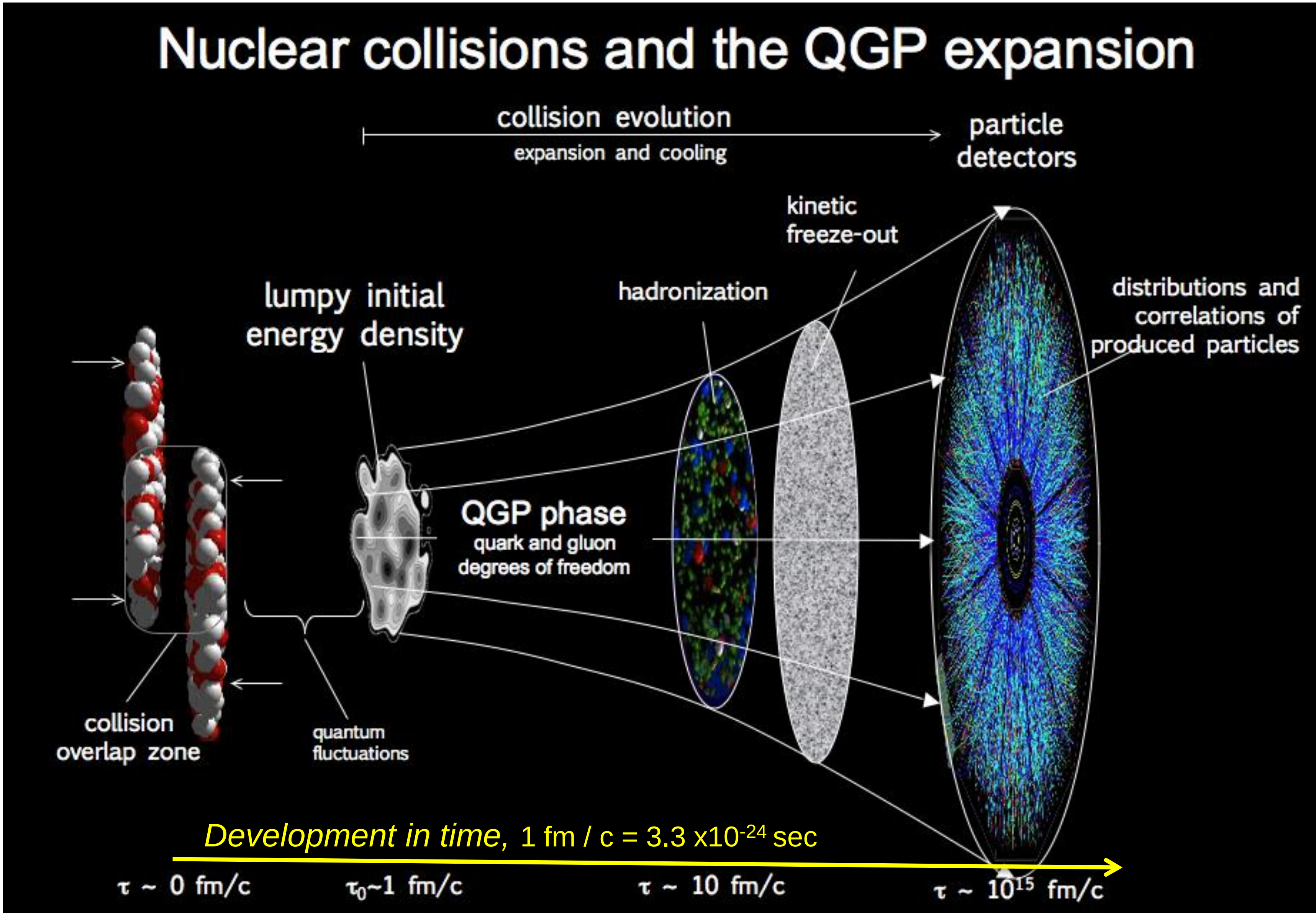
JINR budget expenditure in the current 7-year plan



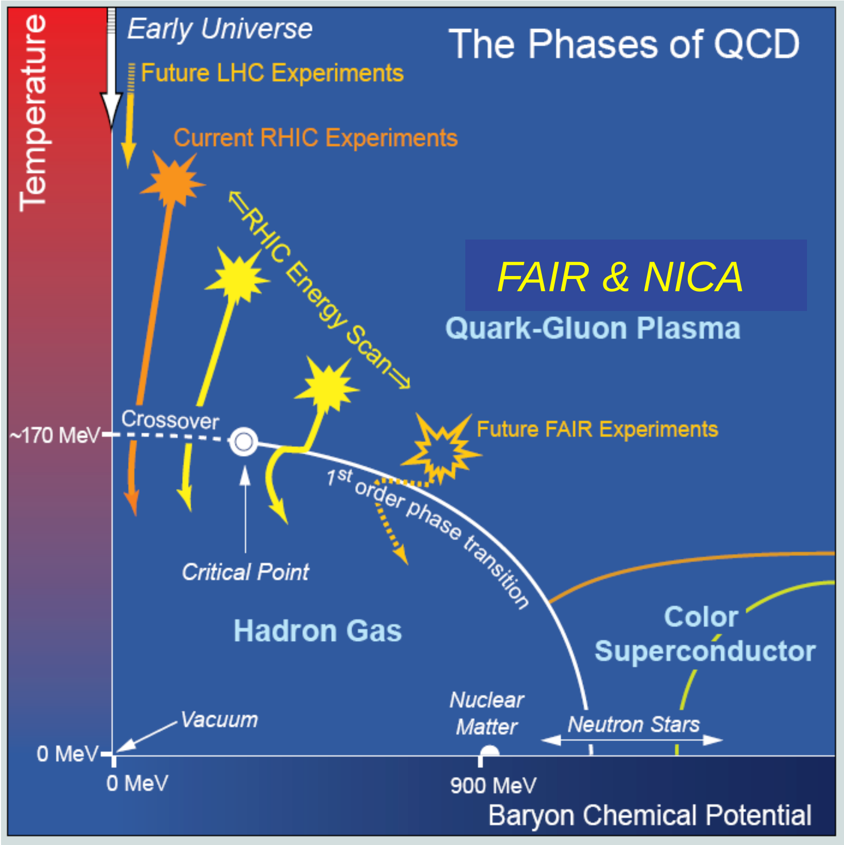
mini "Big Bang" in the laboratory

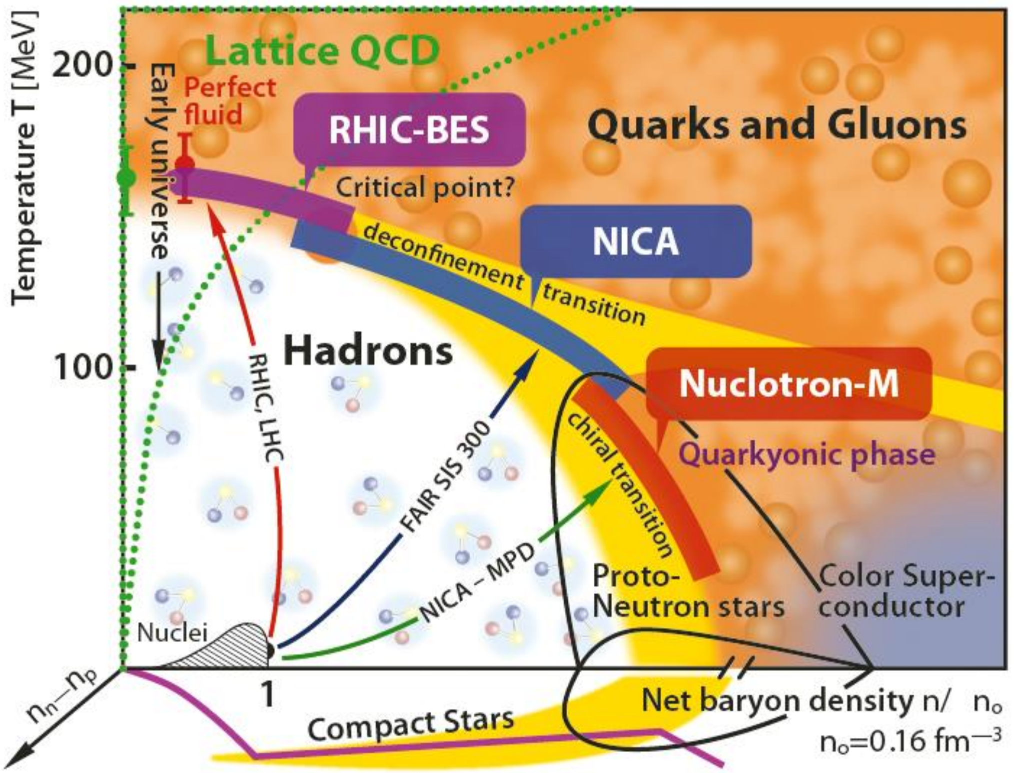


Big Bang	Q-G plasma	p & n formation	low mass nuclei formation	neutral atoms formation	star formation	dispersion of massive elements	Today
T	$>10^{1[illegible]}$ K	10^{12} K	10^{9} K	4000 K	20 - 3 K	< 20 K	3 K
time	$10^{-[illegible]}$ s	10^{-4} s	3 min	400 k yr	10^{9} yr	$> 10^{9}$ yr	$13.5\ 10^{9}$ yr


Nuclear collisions and the QGP expansion
collision evolution
expansion and cooling
particle detectors
kinetic freeze-out
hadronization
lumpy initial energy density
distributions and correlations of produced particles
QGP phase
quark and gluon degrees of freedom
collision overlap zone
quantum fluctuations
Development in time, 1 fm / c = 3.3 x10^-24 sec
τ ~ 0 fm/c
τ0~1 fm/c
τ ~ 10 fm/c
τ ~ 10^15 fm/c

QCD phase diagram

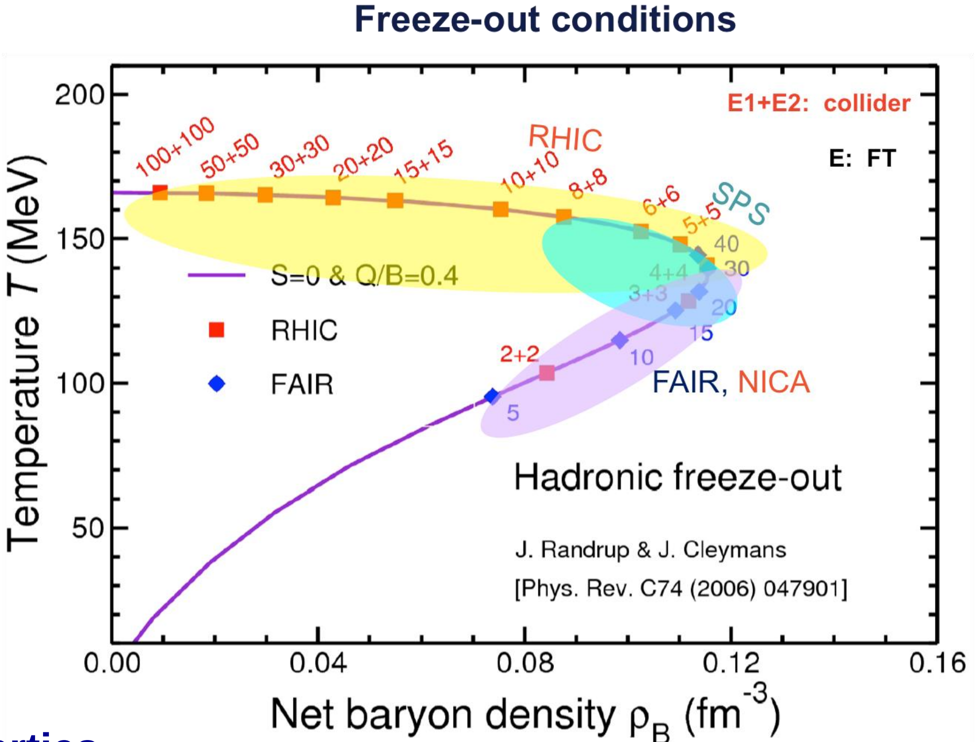




Physics at NICA

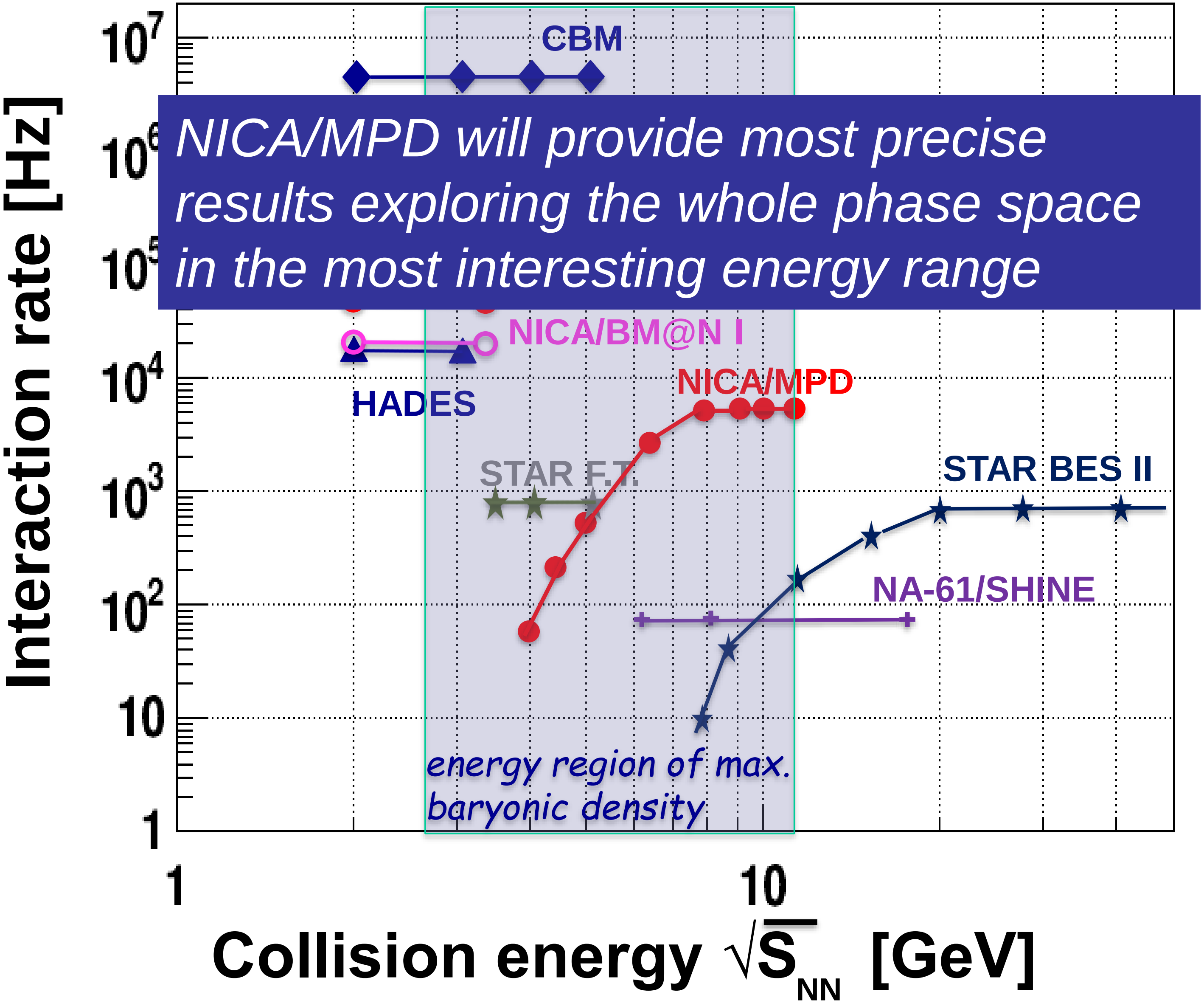
Quark-gluon matter at NICA :

- *Highest net baryon density*
- *Energy range covers onset of deconfinement*
- *Complementary to the RHIC/BES, FAIR and CERN experimental programs*



- **Bulk properties, EOS** - *particle yields & spectra, ratios, femtoscopy, flow*
- **In-Medium modification of hadron properties**
- **Deconfinement (chiral), phase transition at high ρ_B** - *enhanced strangeness production*
- **QCD Critical Point -** *event-by-event fluctuations & correlations*
- **Strangeness in nuclear matter** - *hypernuclei*

Present and future heavy ion experiments

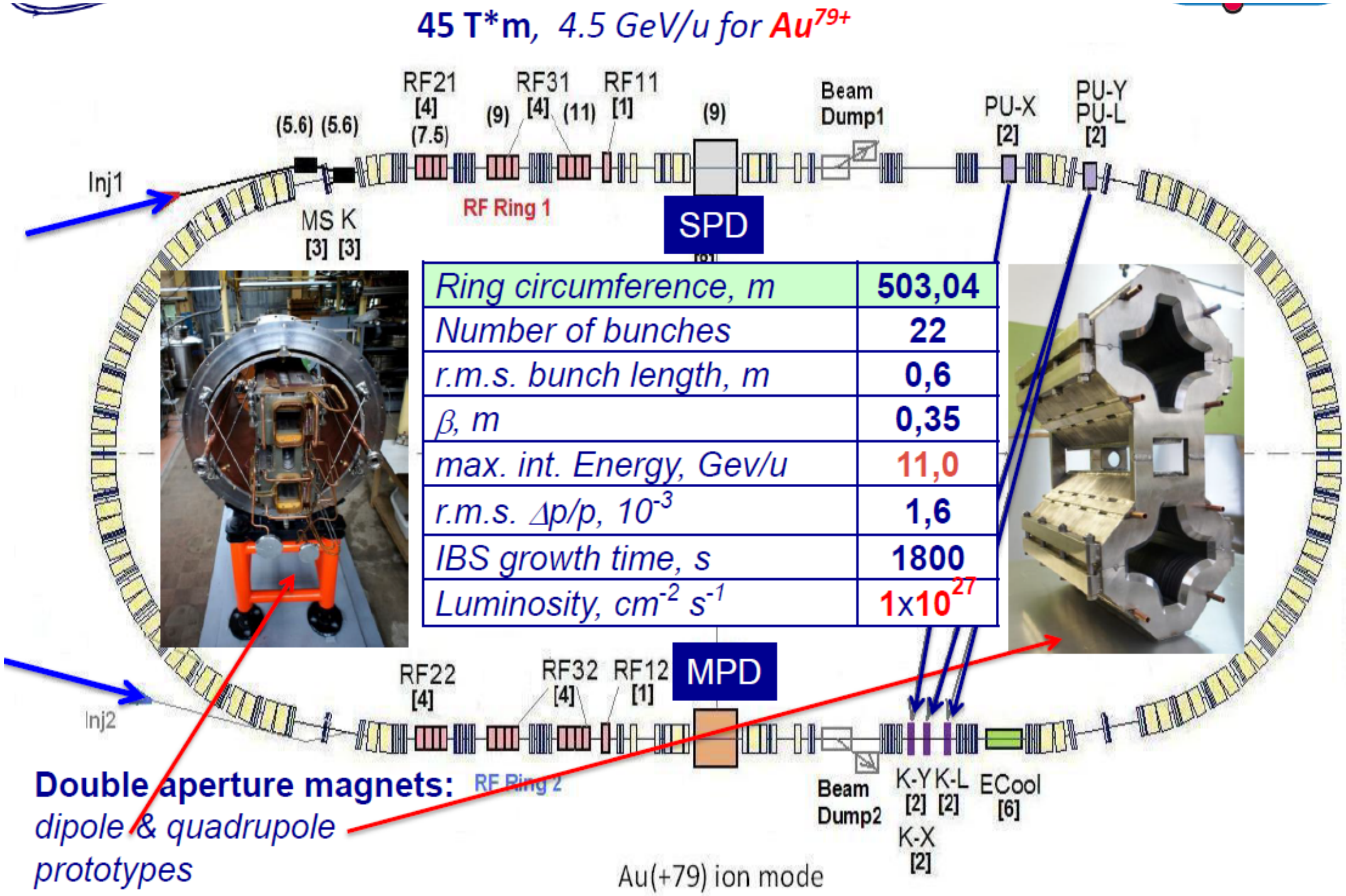


R&D plans and funds for 2018

- 2018 – 1 029 k$
- 2019 – 1 702 k$
- 2020 – 13 500 k$
- 2021 – 1 013 k$
- 2022 – 106 k$
- 2023 – 2 000 k$

This funding profile should be revised according to a schedule that has to be defined in a near future.

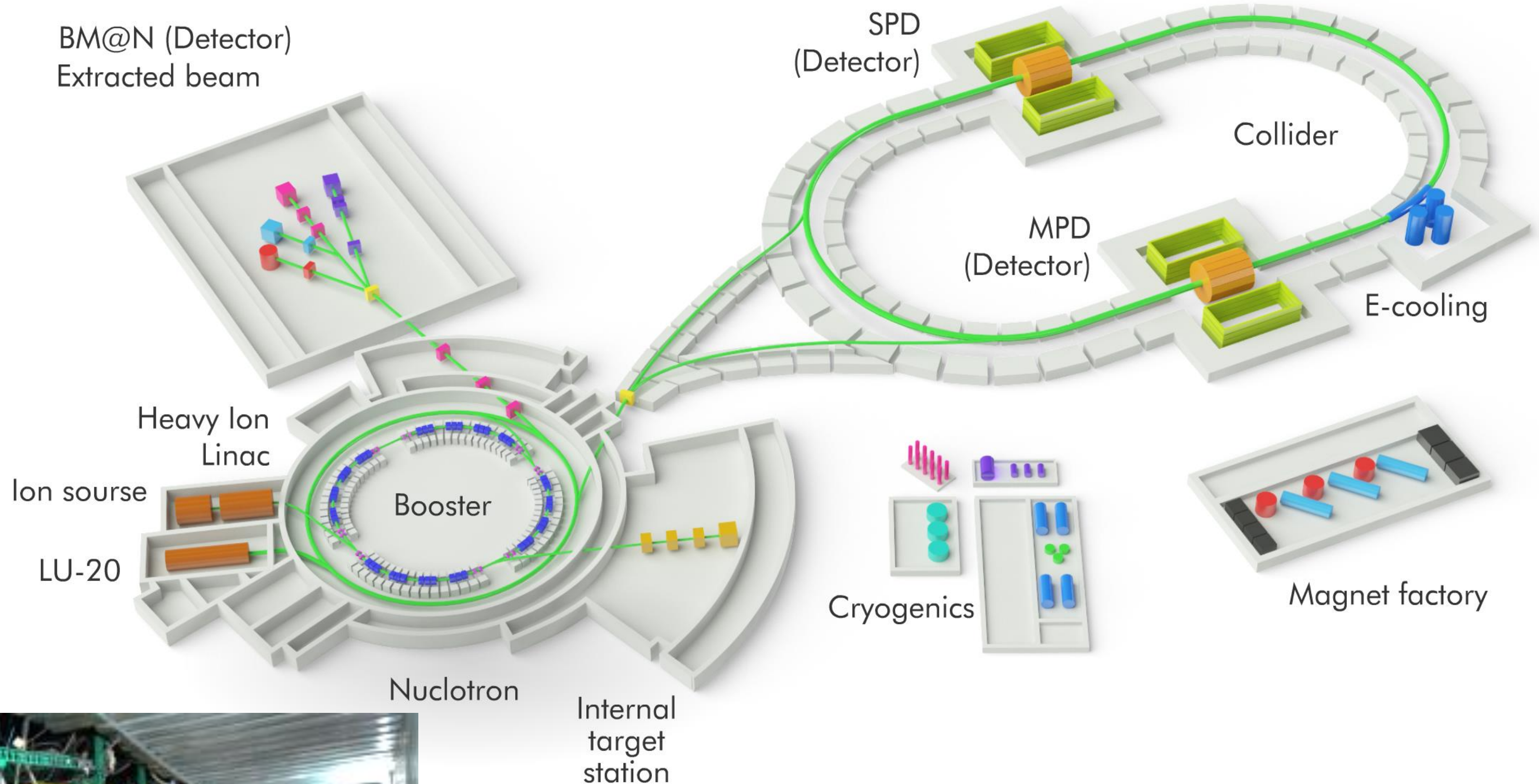
45 T*m, *4.5 GeV/u for* Au^{79+}



Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. int. Energy, Gev/u	**11,0**
r.m.s. Δp/p, 10^{-3}	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	1×10^{27}

Double aperture magnets:
dipole & quadrupole
prototypes

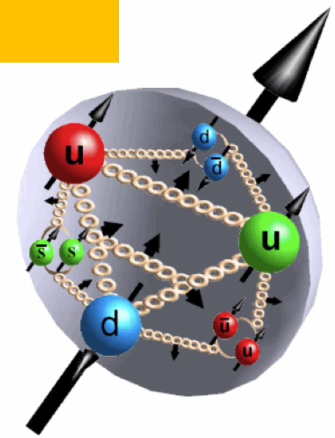
The NICA complex



Nucleon spin structure

Sum rule:

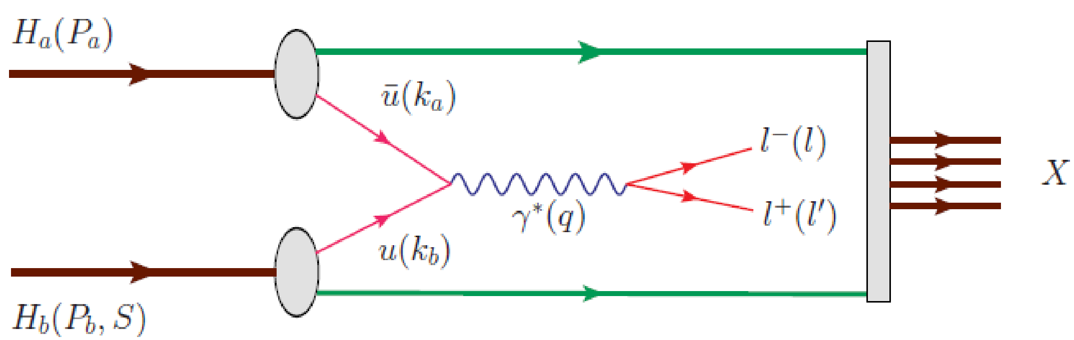
$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g.$$



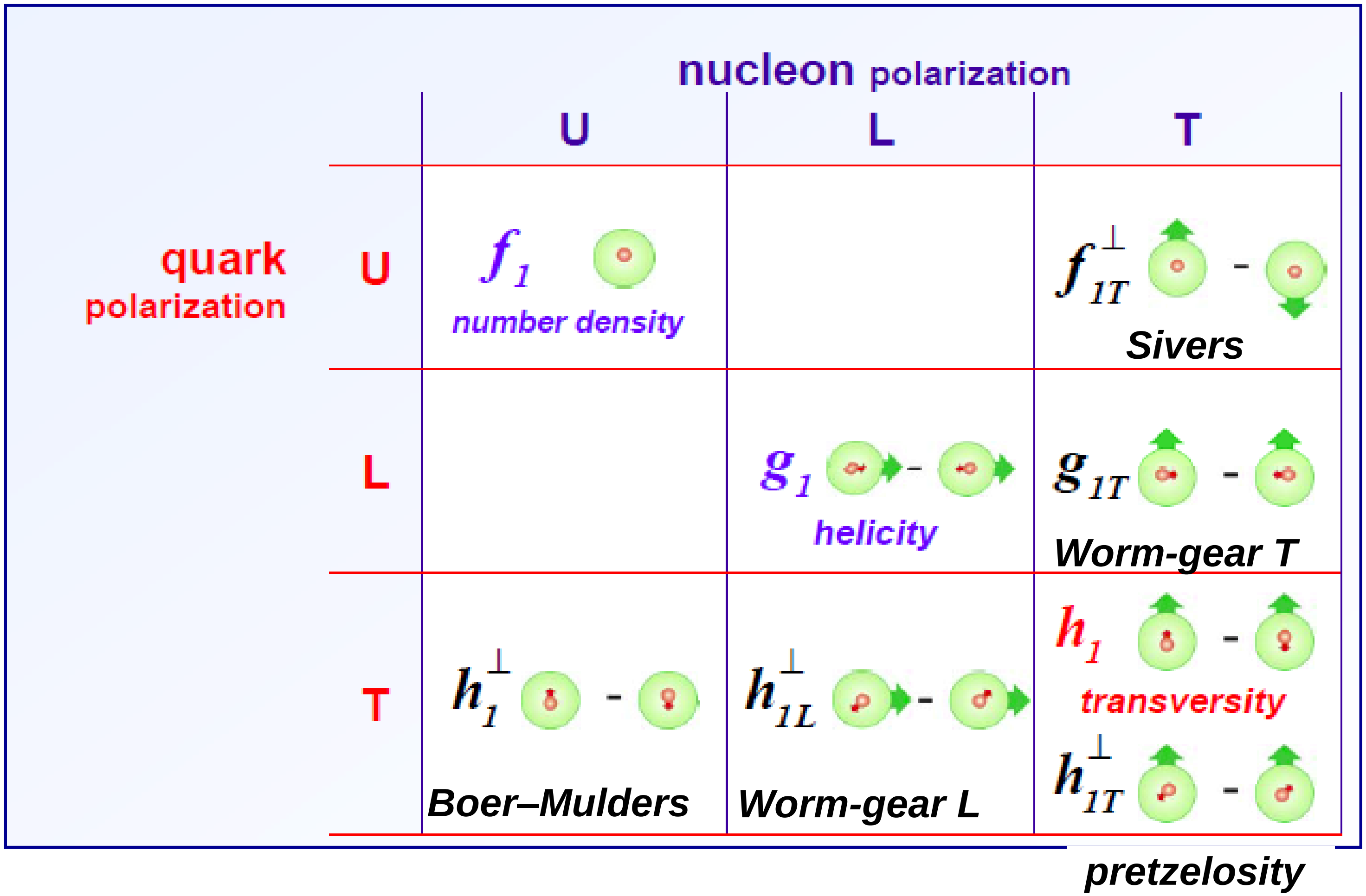
Nucleon spin structure study using the Matveev-Muradyan-Tavkhelidze-Drell-Yan mechanism, DVCS & SIDIS processes (*new PDFs*):

- *8 intrinsic-transverse-momentum dependent PDFs at leading twist*
- *azimuthal asymmetries with different angular modulations in the hadron and spin azimuthal angles, Φ_h and Φ_s*

Direct photons production (*gluon polarization*)



nucleon vs quark polarizations



Experiments studying nucleon spin structure

experiment	CERN, COMPASS-II	FAIR, PANDA	FNAL, E-906	RHIC, STAR	RHIC-PHENIX	NICA, SPD
mode	F.T.	F.T.	F.T.	collider	collider	collider
Beam/target	π- , p	anti-p, p	π- , p	pp	pp	pp, pd,dd
Polarization:b/t	0; 0.8	0; 0	0; 0	0.5	0.5	0.7
Luminosity	$2{\cdot}10^{33}$	$2{\cdot}10^{32}$	$3.5{\cdot}10^{35}$	$5{\cdot}10^{32}$	$5{\cdot}10^{32}$	10^{32}
$\sqrt{s}$, GeV	14	6	16	200, 500	200, 500	10 - 26
$x_{1(beam)}$ range	0.1-0.9	0.1-0.6	0.1-0.5	0.03-1.0	0.03-1.0	0.1-0.8
q_T, GeV	0.5 -4.0	0.5 -1.5	0.5 -3.0	1.0 -10.0	1.0 -10.0	0.5 -6.0
Lepton pairs,	μ-μ+	μ-μ+	μ-μ+	μ-μ+	μ-μ+	μ-μ+, e+e-
Data taking	2015	>2025	2013	>2016	>2016	>2020
Transversity	NO	NO	NO	YES	YES	YES
Boer-Mulders	YES	YES	YES	YES	YES	YES
Sivers	YES	YES	YES	YES	YES	YES
Pretzelosity	NO	NO	NO	NO	YES	YES
Worm Gear	NO	NO	NO	NO	NO	YES
Direct γ	NO	NO	NO	YES	YES	YES

Experiments studying Drell-Yan pair production

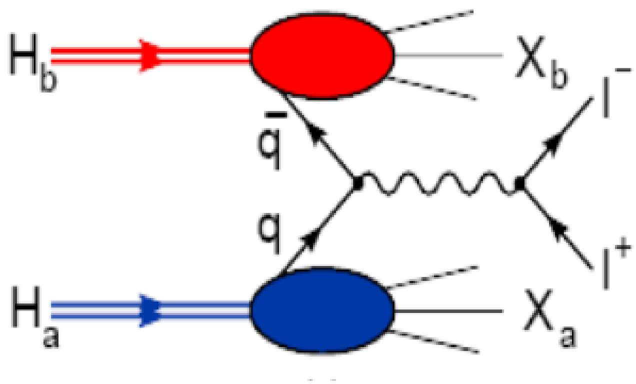
The experiments at the SPD will have a number of advantages for DY measurements related to the nucleon structure studies. These advantages include:

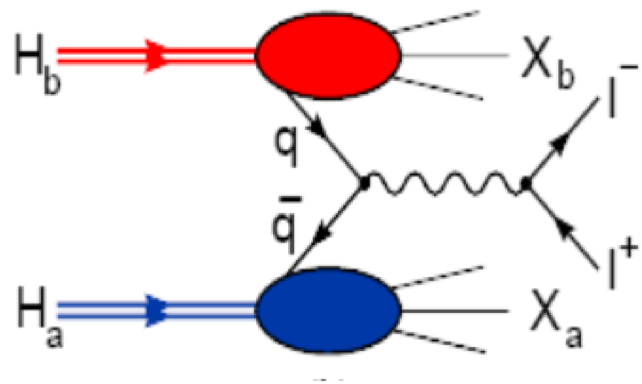
- running with pp, pd and dd beams,
- scan of the effects over a range of beam energies,
- Measurements via muon and electron-positron pairs simultaneously,
- running with non-polarized, transverse and longitudinally polarized beams and their combinations.

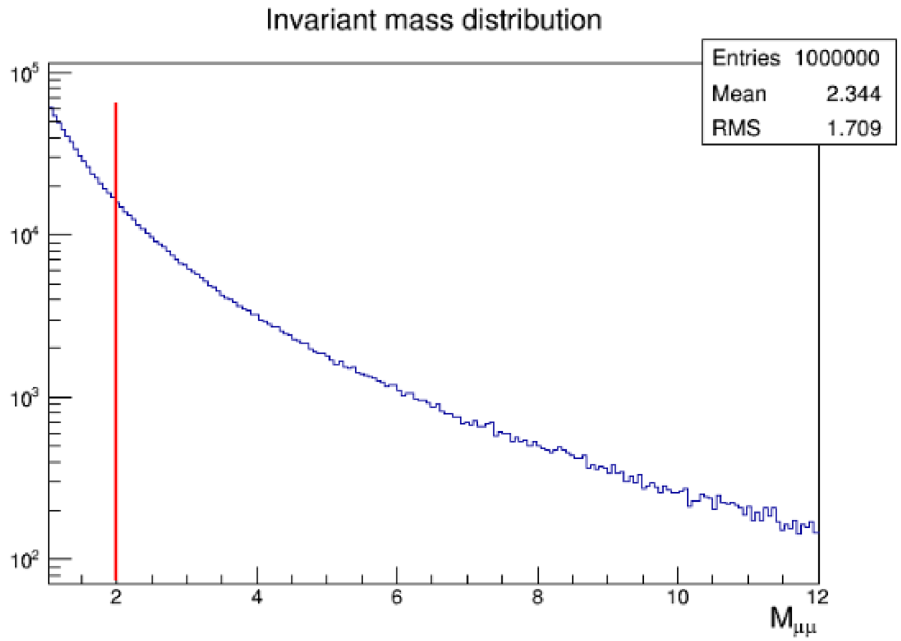
Experiment	CERN, COMPASS-II	FAIR, PANDA	FNAL, E-906	RHIC, STAR	RHIC-PHENIX	NICA, SPD
mode	*fixed target*	*fixed target*	*fixed target*	*collider*	*collider*	*collider*
Beam/target	*π-, p*	*anti-p, p*	*π-, p*	*pp*	*pp*	*pp, pd,dd*
Polarization:b/t	*0; 0.8*	*0; 0*	*0; 0*	*0.5*	*0.5*	*0.9*
Luminosity	$2\cdot10^{33}$	$2\cdot10^{32}$	$3.5\cdot10^{35}$	$5\cdot10^{32}$	$5\cdot10^{32}$	10^{32}
√s, GeV	*14*	*6*	*16*	*200, 500*	*200, 500*	*10-26*
$x_{1(beam)}$ *range*	*0.1-0.9*	*0.1-0.6*	*0.1-0.5*	*0.03-1.0*	*0.03-1.0*	*0.1-0.8*
q_T, *GeV*	*0.5 -4.0*	*0.5 -1.5*	*0.5 -3.0*	*1.0 -10.0*	*1.0 -10.0*	*0.5 -6.0*
Lepton pairs,	*μ-μ+*	*μ-μ+*	*μ-μ+*	*μ-μ+*	*μ-μ+*	*μ-μ+, e+e-*
Data taking	*2014*	*>2018*	*2013*	*>2016*	*>2016*	*>2018*
Transversity	NO	NO	NO	YES	YES	YES
Boer-Mulders	YES	YES	YES	YES	YES	YES
Sivers	YES	YES	YES	YES	YES	YES
Pretzelosity	YES (?)	NO	NO	NO	YES	YES
Worm Gear	YES (?)	NO	NO	NO	NO	YES
J/Ψ	YES	YES	NO	NO	NO	YES
Flavour separ	NO	NO	YES	NO	NO	YES
Direct γ	NO	NO	NO	YES	YES	YES

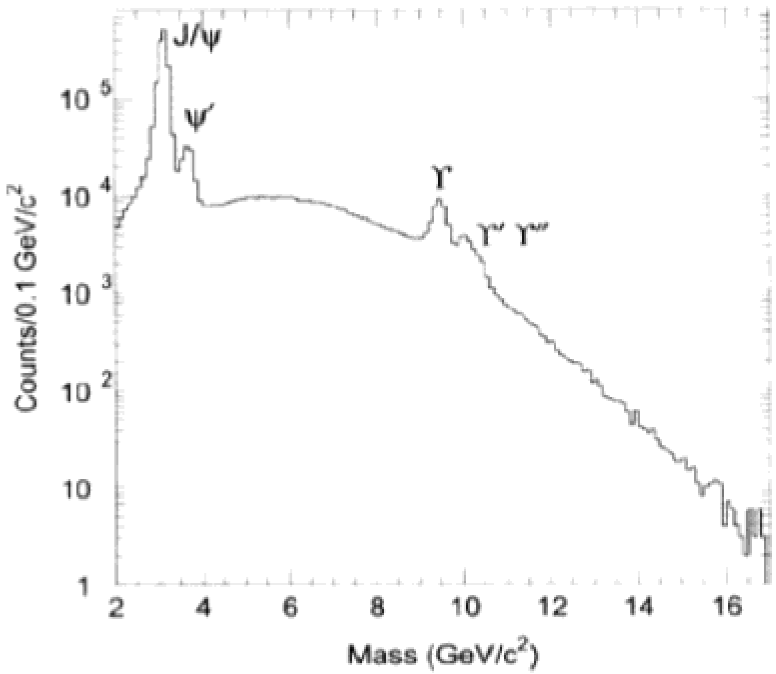
The above advantages permit, for the first time, to perform comprehensive studies of all leading twist PDFs of the nucleon in a single experiment with minimal systematic errors.

Drell-Yan pairs in the SPD

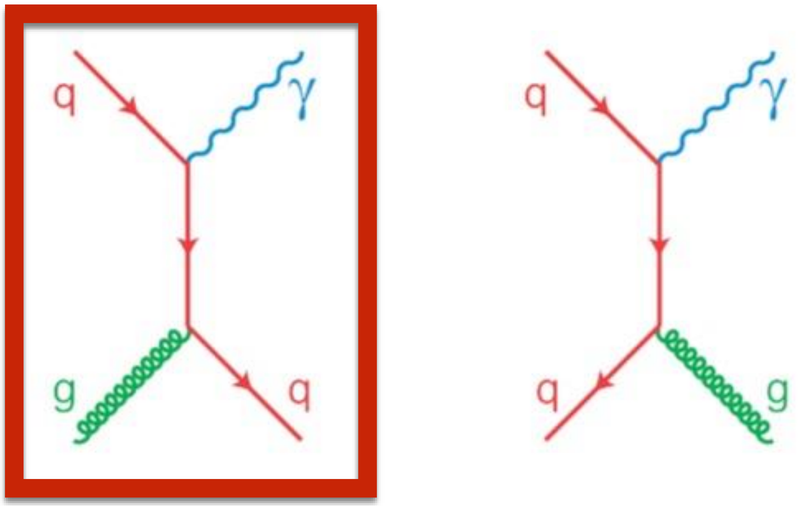


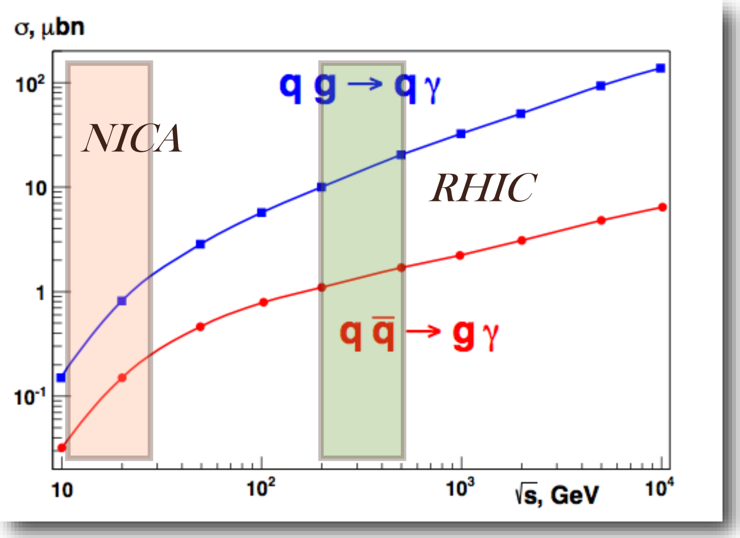






Prompt photons: Gluon Compton scattering gives us an access to the gluon content of the proton





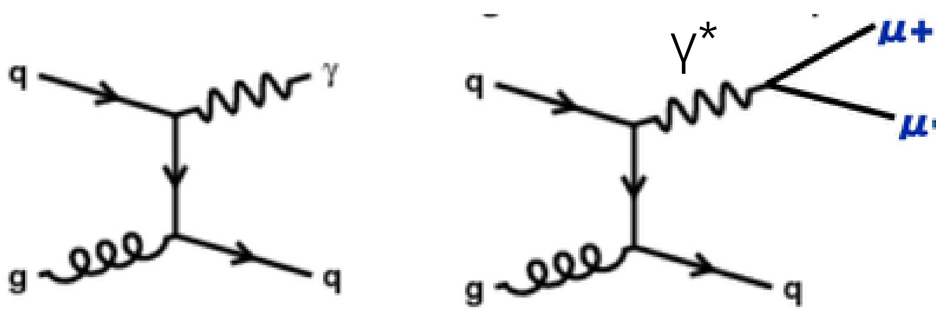
$$\sigma^{\uparrow} - \sigma^{\downarrow} = \sum_i \int_{x_{min}}^{1} dx_a \int d^2\mathbf{k}_{Ta} d^2\mathbf{k}_{Tb} \frac{x_a x_b}{x_a - (p_T/\sqrt{s})\, e^y} \left[q_i(x_a, \mathbf{k}_{Ta}) \Delta_N G(x_b, \mathbf{k}_{Tb}) \right.$$
$$\left. \times \frac{d\hat{\sigma}}{d\hat{t}}(q_i G \to q_i \gamma) + G(x_a, \mathbf{k}_{Ta}) \Delta_N q_i(x_b, \mathbf{k}_{Tb}) \frac{d\hat{\sigma}}{d\hat{t}}(G q_i \to q_i \gamma) \right]$$

Longitudinal beam polarization: access to gluon polarization Δg/g

$$A_{LL} \approx \frac{\Delta g(x_1)}{g(x_1)} \cdot \left[\frac{\sum_q e_q^2 \left[\Delta q(x_2) + \Delta \bar{q}(x_2)\right]}{\sum_q e_q^2 \left[q(x_2) + \bar{q}(x_2)\right]} \right] + (1 \leftrightarrow 2)$$

Complementarity of prompt photon and low-mass DY measurements

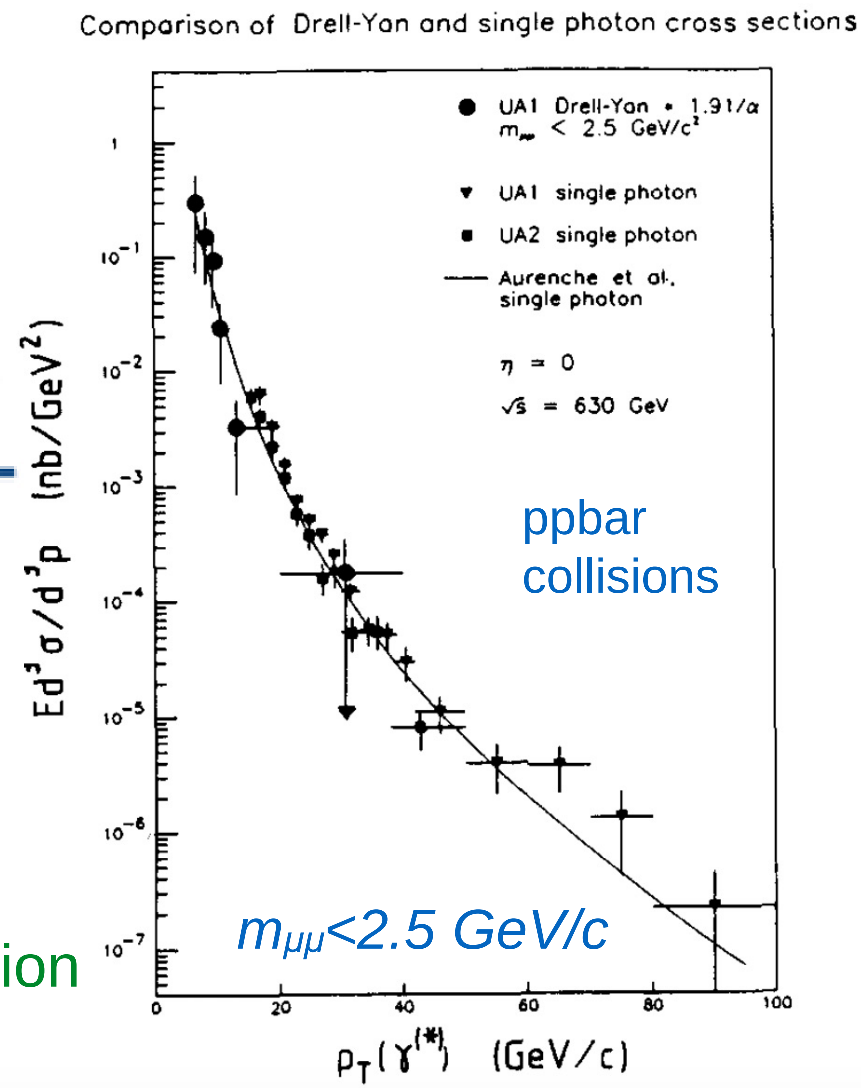
Production of low-mass dimuon pairs is a process very similar to prompt photon production



— two orders of magnitude smaller cross section for DY production

— possibility to access the low-p_T region

Phys.Lett. B209 (1988) 397-406 (1988)

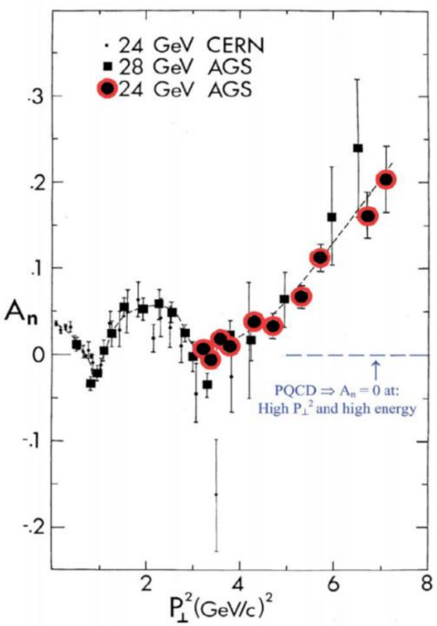


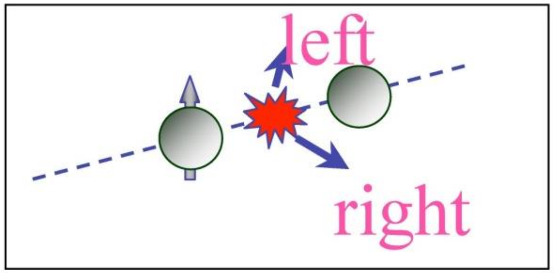
Why prompt photons?

- Unpolarized and polarized physics with prompt photons looks very attractive
- All the measurements at energy scale ~20 GeV were performed with pion and proton beams only 20-30 years ago It is a good time to come back with new level of experimental techniques and theoretical understanding
- We have good chance to perform such kind of measurements at SPD detector
- Background conditions for studies with prompt photons are quite hard. So the SPD detector should be really optimized.

Asymmetries in high p_T hadron production

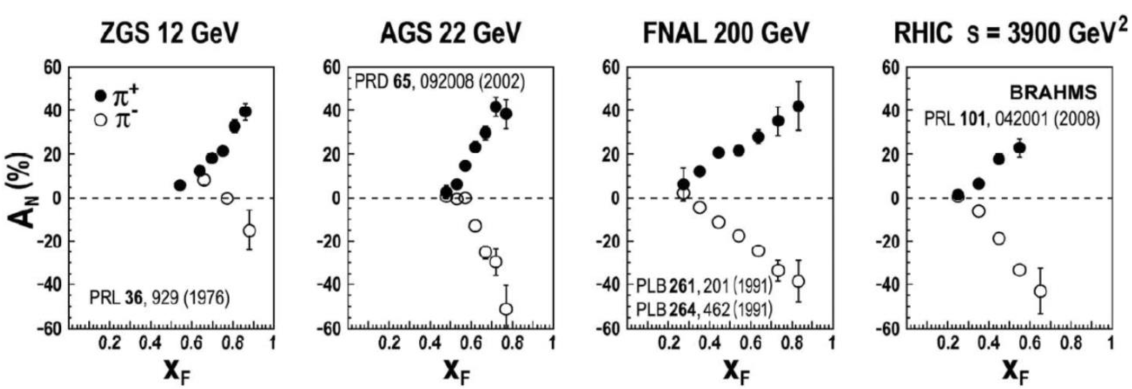
- Diquark properties.
- Confinement laws.
- Nature of the huge spin effects.
- Deuteron spin structure.
- Properties of the plain NΛ- and NK-interactions.
- Nature and properties of the cold super dense baryonic matter (CsDBM) (pA and AA).
- Dilepton production puzzle in np-interaction.



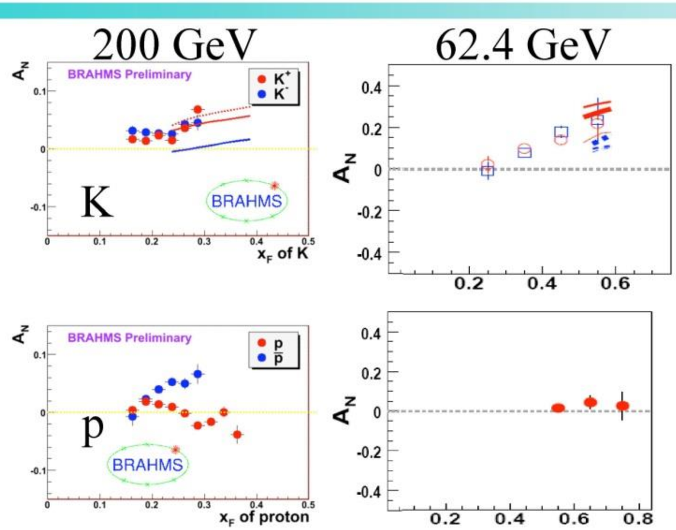


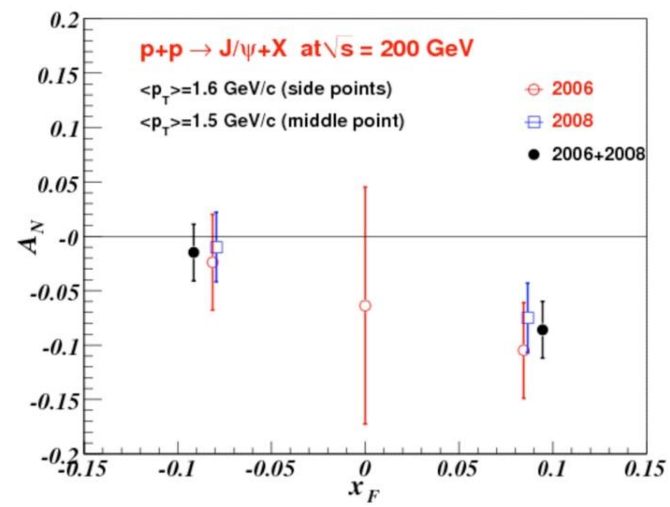
INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

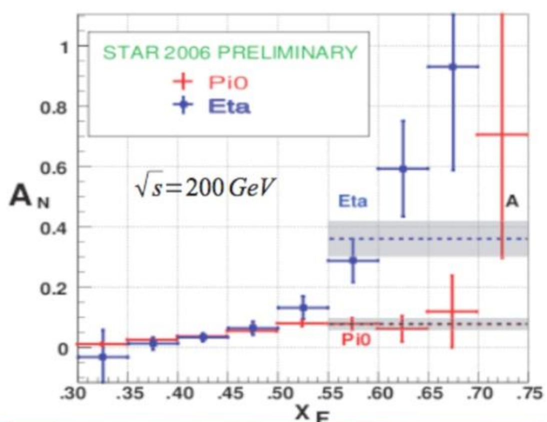
C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009

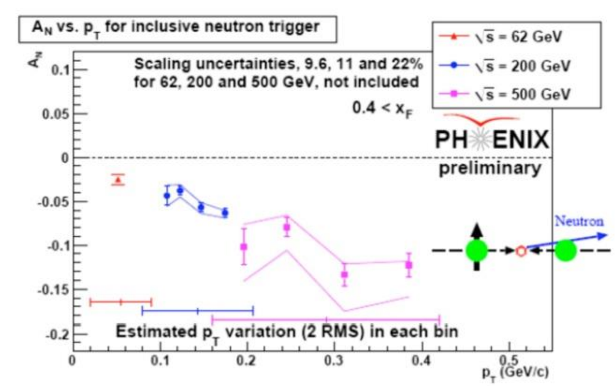


More transverse spin results (surprises)









K.Boyle, Spin Physics at RHIC, EQCD 2011

See talks by S.Shimansky and A.Krisch given at the SPIN-2012, Dubna

Working groups have been set up:

- Interim Steering Committee (13 members)
- Physics program
  - Theory (OV Teryaev)
  - Simulations (AP Nagaytsev, AV Guskov, SS Shimanskij)
  - Local polarimetry (VP Ladygin)
- Detector
  - Overall design (VA Anosov, IV Moshkovsky)
  - Magnet (AD Kovalenko)
  - Vertex detector (NI Zamjatin)
  - Tracking (TL Enik)
  - FEE – Turin ?
  - Trigger & DAQ (AV Koulikov, I. Konorov)
  - TOF-RPC - IHEP Protvino ?
  - ECAL - OP Gavrishchuk
  - Muon range system (GD Alekseev)
- Software (OV Rogachevski, A Tkachenko)

Roadmap

- Writing up of a formal JINR project for the SPD design (*i.e. for preparation of the Conceptual and Technical Design Reports*) and submission of the project to the PAC for Particle Physics:
  - status report presented at the PAC meeting in Jan. 2018;
  - submission of the application to the PAC in Nov. 2018 for their meeting in Jan. 2019;
- Setting up of the collaboration and election of its management bodies (2019);
- Signing of an MoU based on "*Regulations for the organization of experiments conducted by international collaborations using the capabilities of the JINR basic facilities*" *http://www.jinr.ru/wp-content/uploads/JINR_Docs/Regulation_for_the_organization_of_experiments_eng.doc* (2019).

Roadmap (cont'd)

- Preparation of the Conceptual Design Report (2019);
- Preparation of the Technical Design Report, including prototyping – first stage (2020 – 2022), second stage (2023);
- Construction of the detector (2022-2025);
- First measurements – 2025…