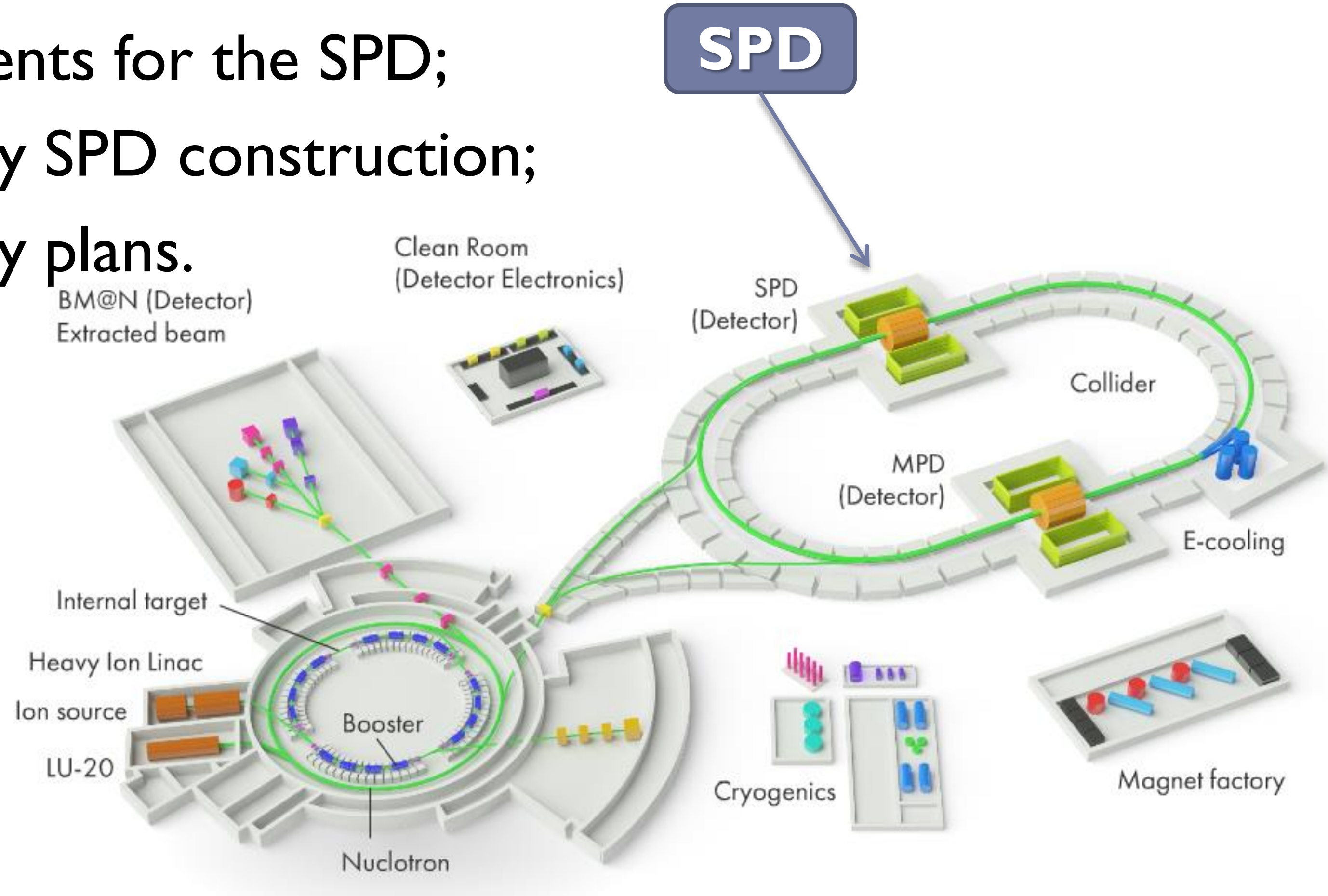
First Open Day of the NICA Complex

Spin physics at NICA

Gribowsky Alexandr on behalf of SPD project team

Outline

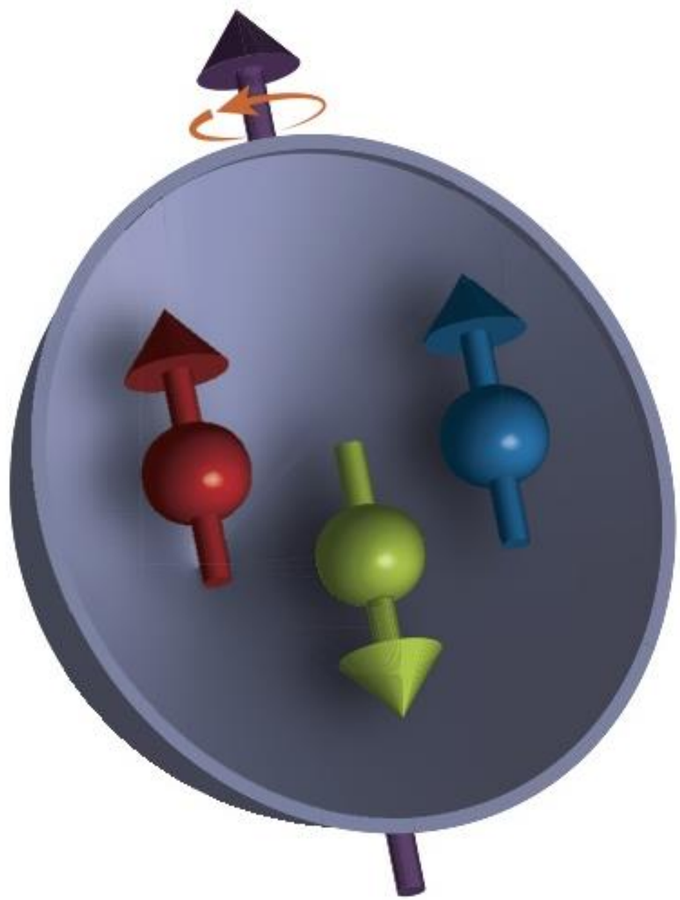
- Nucleon spin structure;
- Physics tasks;
- Requirements for the SPD;
- Preliminary SPD construction;
- Preliminary plans.



Before 1988

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma_{\text{quarks}}$$

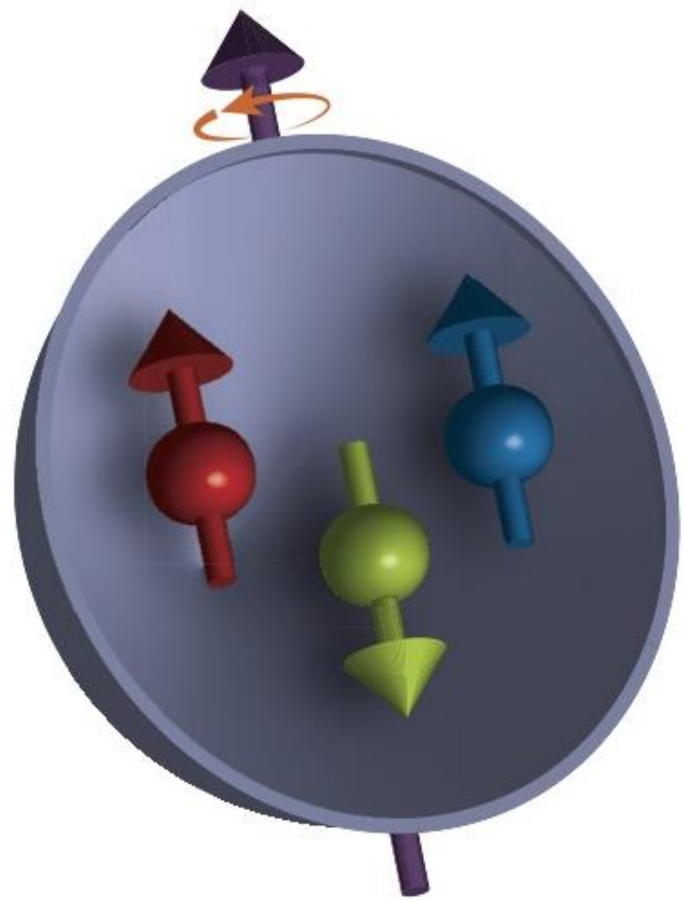
THEORY SHOWS: nucleon spin is carried only by quarks.



Nucleon spin structure

Before 1988

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma_{\text{quarks}}$$



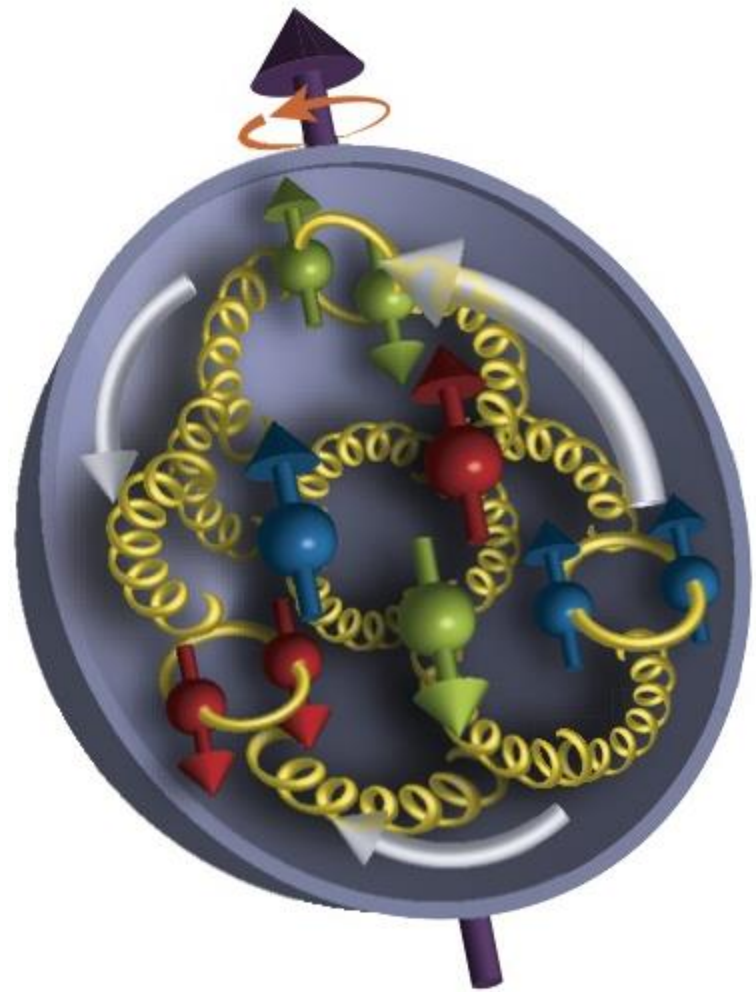
PROBLEM: According to the experimental data, only 30% of a nucleon spin is carried by quarks. Where is the rest of the spin comes from?

Experiment: (*EMC, Nucl. Phys. B 328 (1989) 1*)

After 1988

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{(q+g)}$$

quarks gluons orbital momentum



ΔG -- some experimental constrains available;

L(q+g) – up to now, no experimental data.

Nucleon structure and PDFs

Nucleon \ Quark	U	L	T
U	number density		Boer-Mulders
L		helicity	worm-gear L
T	Sivers	Kotzinian-Mulders worm-gear T	transversity pretzelosity

spin of the nucleon   spin of the quark k_T

PDFs describes different properties

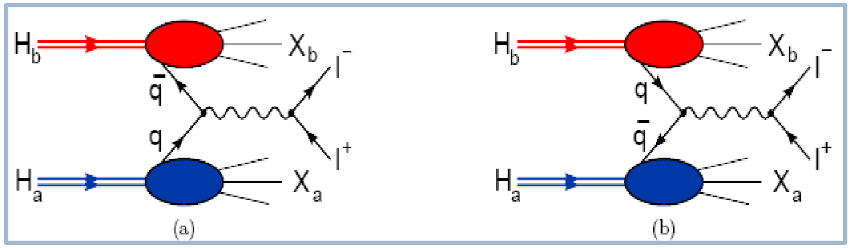
3 PDFs are needed to describe nucleon structure in collinear approximation

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

f_1 -- density of partons in non-polarized nucleon;
g_1 -- helicity , longitudinal polarization of quarks in longitudinally polarized nucleon;
$f^{\perp}_{1T}$ - Sivers, correlation between the transverse polarization of nucleon (transverse spin) and the transverse momentum of non-polarized quarks;
etc…

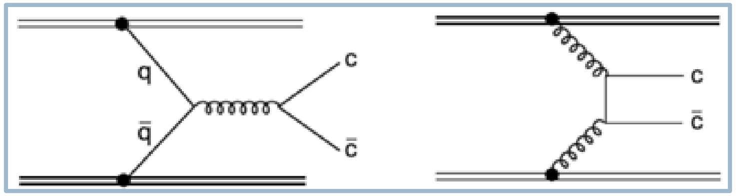
Physics tasks

- Nucleon spin structure studies
  - **Drell-Yan process;**

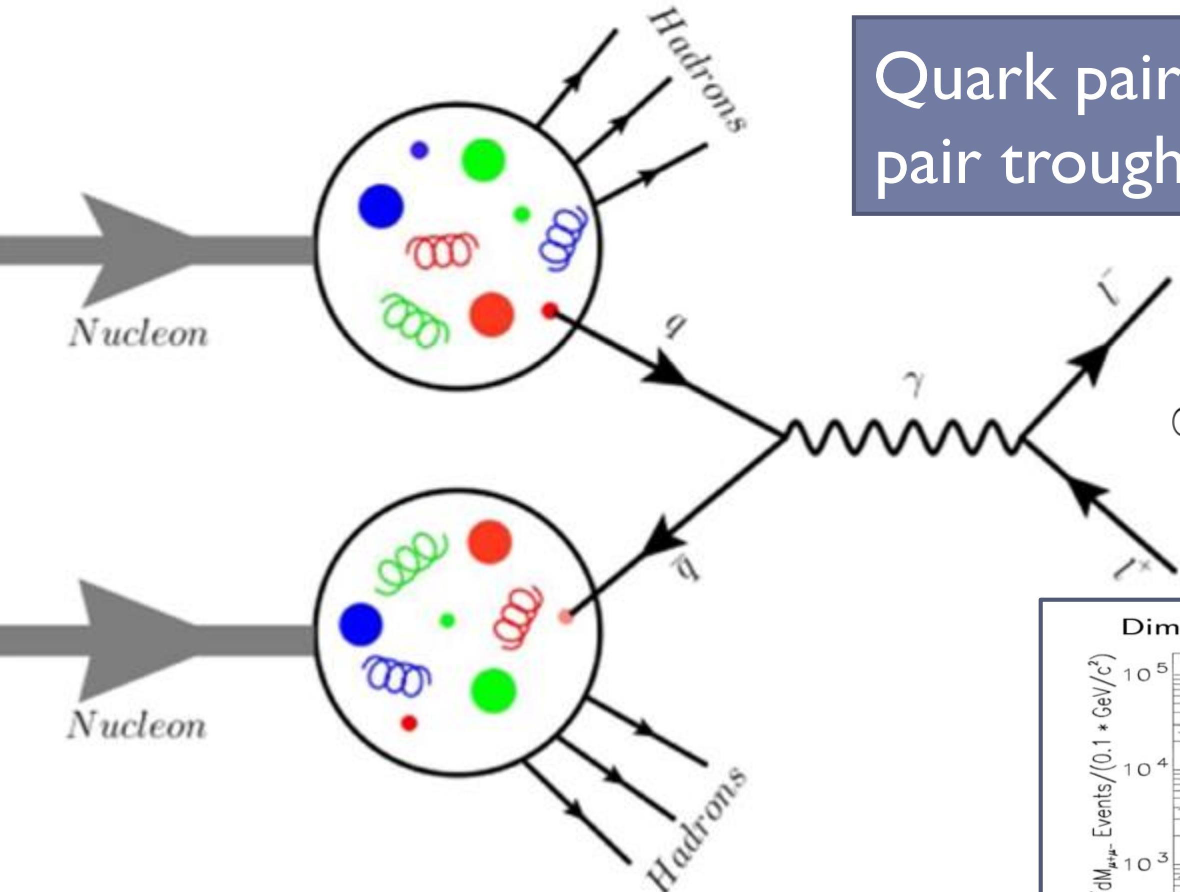


  - **Direct photon production;**

  - **J/ψ (heavy flavor) production;**



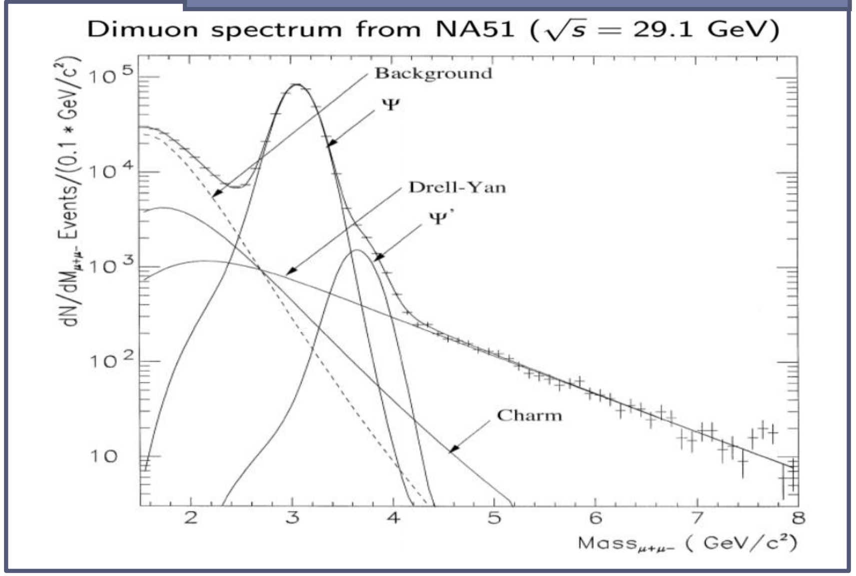
- Spin-dependent effects in elastic pp, pd and dd scattering;
- Spin effects in exclusive hadron production;
- Spin effects in production of hadrons with high p_T ;
- etc….



Quark pair creates lepton (**e**/μ) pair trough virtual photon

$$\propto PDF_{nucl1} \otimes PDF_{nucl2}$$

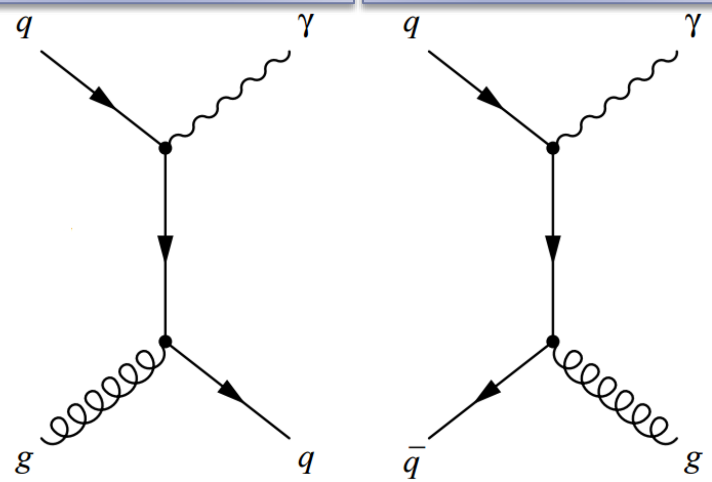
Only heavy μ can be seen



We can use this "virtual photon microscope" to look into nucleons and obtain access to PDFs.

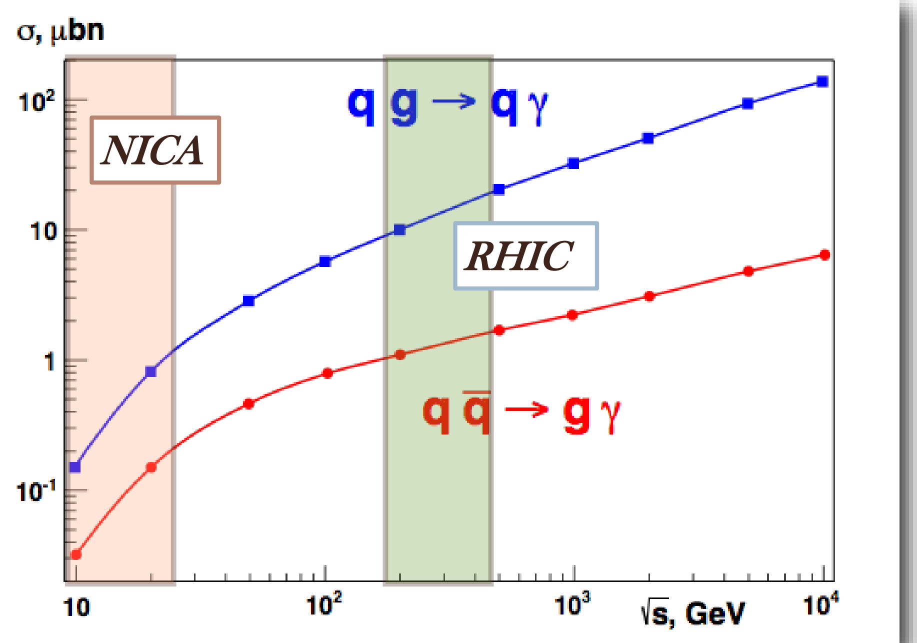
Prompt (direct) photon production

Gluon Compton scattering	Quark-antiquark annihilation



The gluon Compton scattering mechanism is predominant…

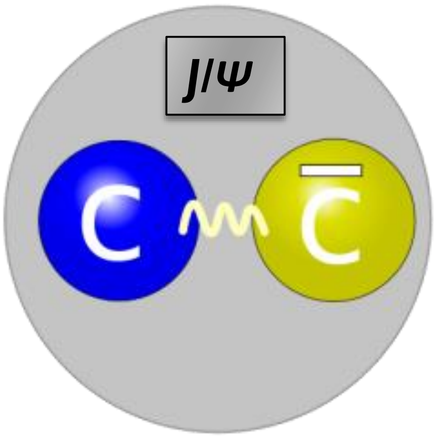
q g→q γ **85%**
q qbar→g γ **15%**



…so we can obtain access to the contribution of gluon to spin of the nucleon and gluon Sivers function.

But we must get rid of background from q qbar→g γ

Charmonium (J/Ψ) production



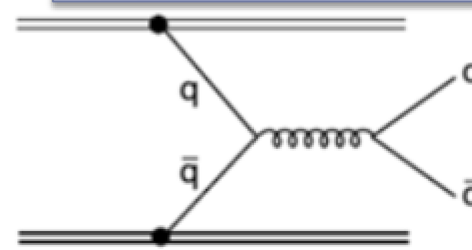
Applicability of the method is limited due the lack of understanding J/ψ production mechanism.

Proton-proton collisions at SPD provide ideal opportunity for verification of theoretical approaches to J/ψ production.

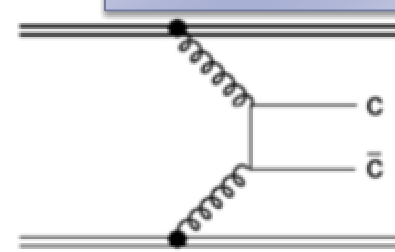
Studying J/Ψ production gives us access to gluon PDFs.

NRQCD

Quark annihilation



Gluon fusion



Requirements for the SPD

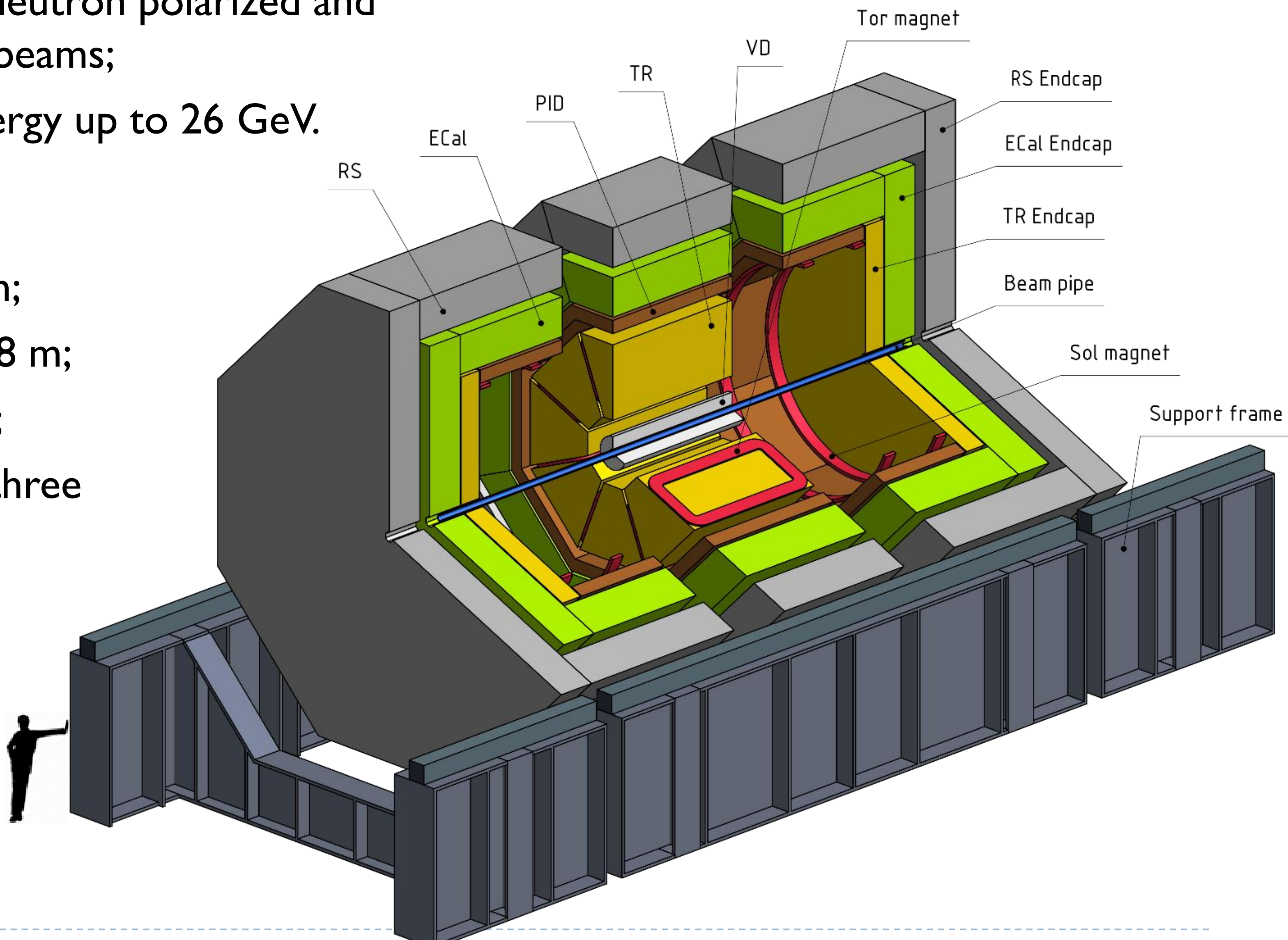
Keeping in mind tasks we can formulate requirements for SPD:

- close to 4π geometrical acceptance;
- high-precision (~50 μm) and fast vertex detector;
- high-precision (~100 μm) and fast tracking system;
- good particle identification capabilities;
- low material budget over the track paths;
- trigger and DAQ system able to cope with event rates at luminosity of 10^{32} $cm^{-2}s^{-1}$;
- modularity and easy access to the detector elements, that makes possible further reconfiguration and upgrade of the facility.

Spin Physics Detector: View

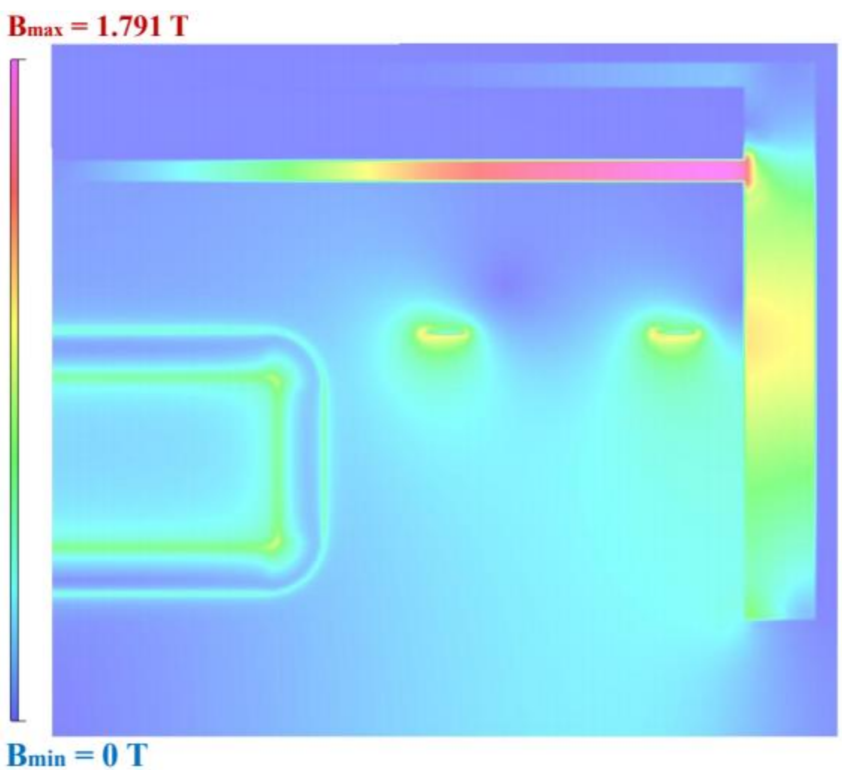
- Proton and deutron polarized and unpolarized beams;
- Collision energy up to 26 GeV.

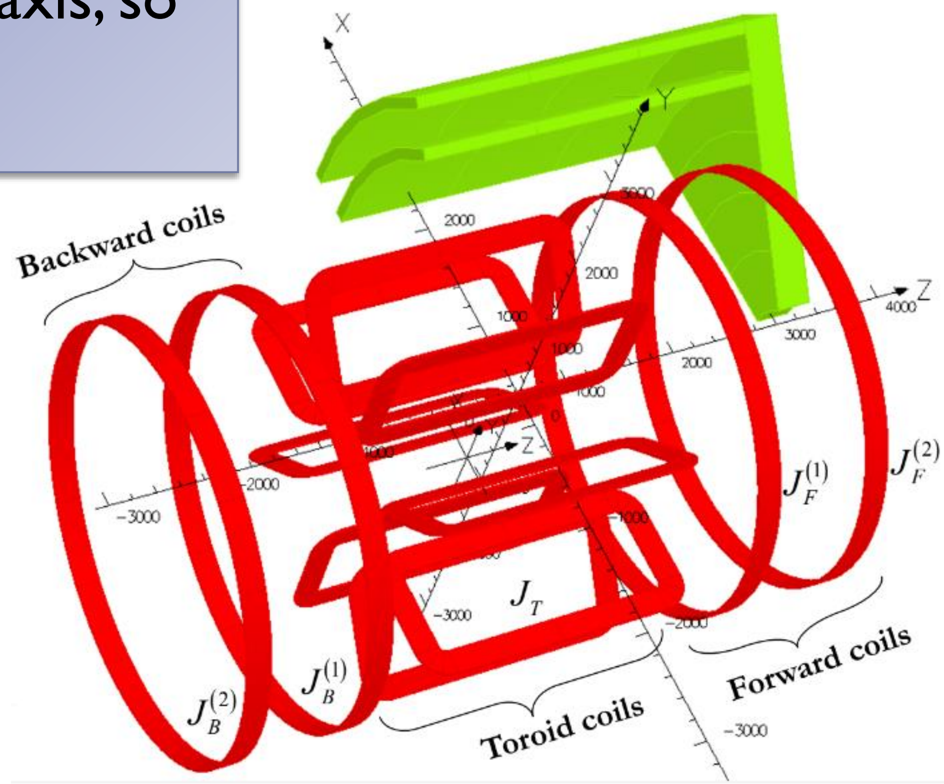
- Length: 9.2 m;
- Diameter: 6.8 m;
- Mass: 1800 t;
- Consists of three modules;
- Easy to rearrange.



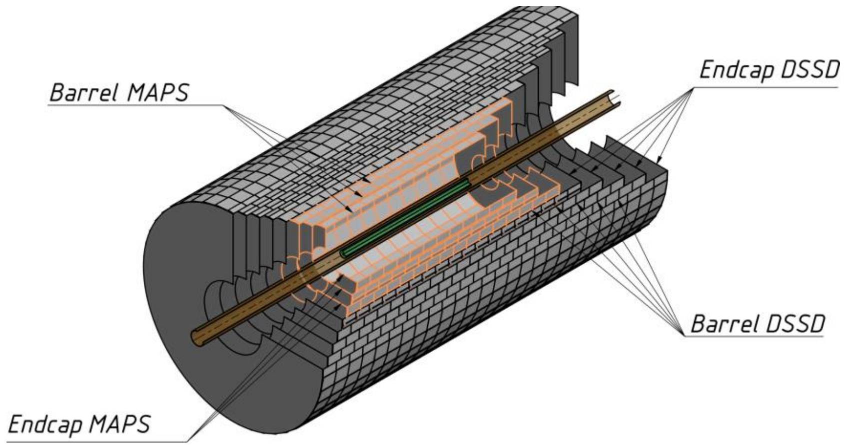
Advantage:

- Magnetic field is close to 0 at Z axis, so it won't influence polarization.

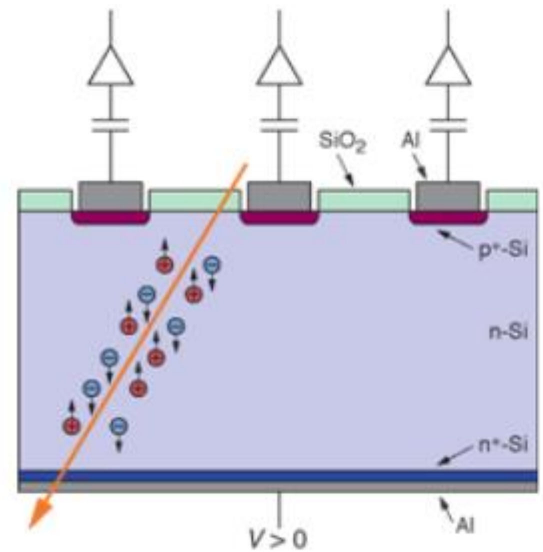




Vertex detector (Inner tracker)



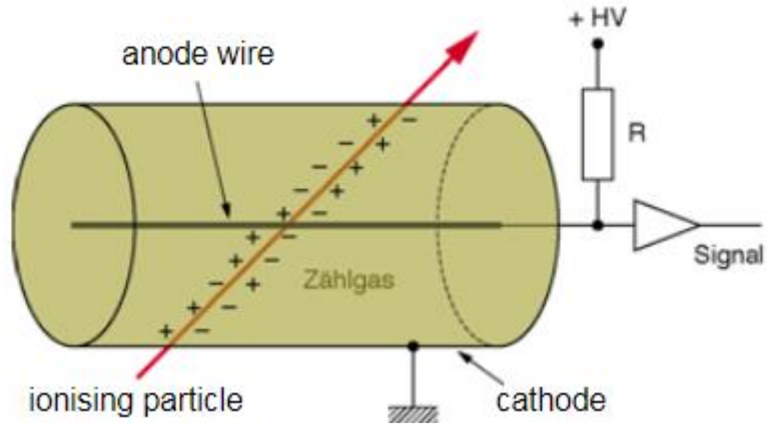
Charged particle creates electron/hole pairs, which migrates to electrodes creating signal in nearest strips

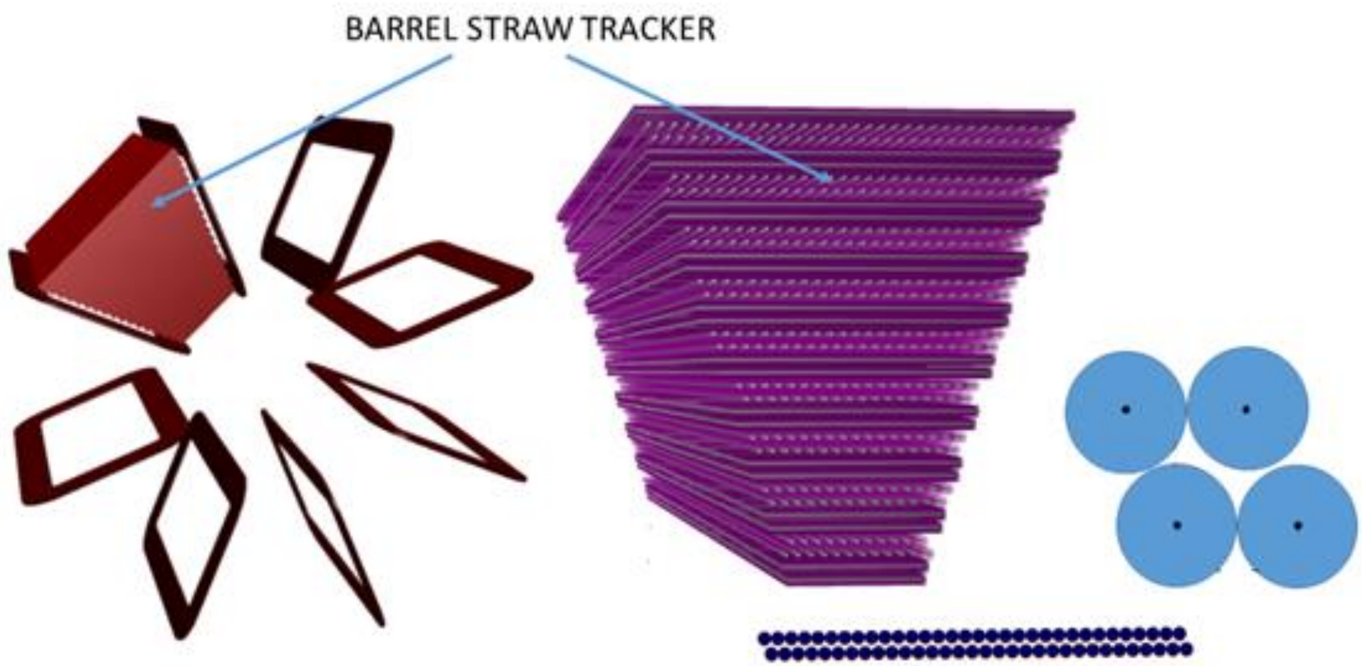


- Silicon vertex detector around the beam pipe;
- Several layers of double sided silicon strips and MAPS;
- Optimized number of layers w.r.t. material budget;
- Goal: few tens of μm resolution for the vertex reconstruction.

Central tracker

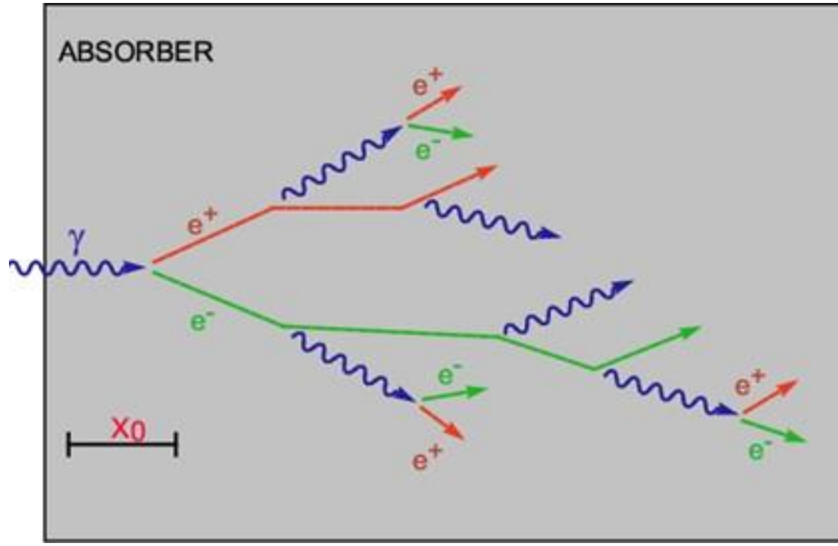
- Minimum material on the particle tracks (X_0 ~ 0.1);
- Time (~ 100 ns) and spatial resolution (~100 µm);
- Expected particle rates (DAQ rates) ~ MHz;
- Technology developed also in JINR, production workshops available

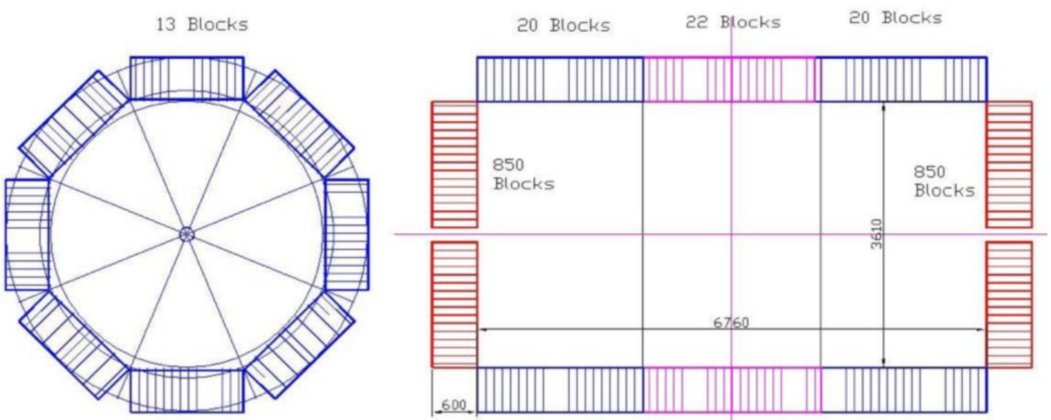




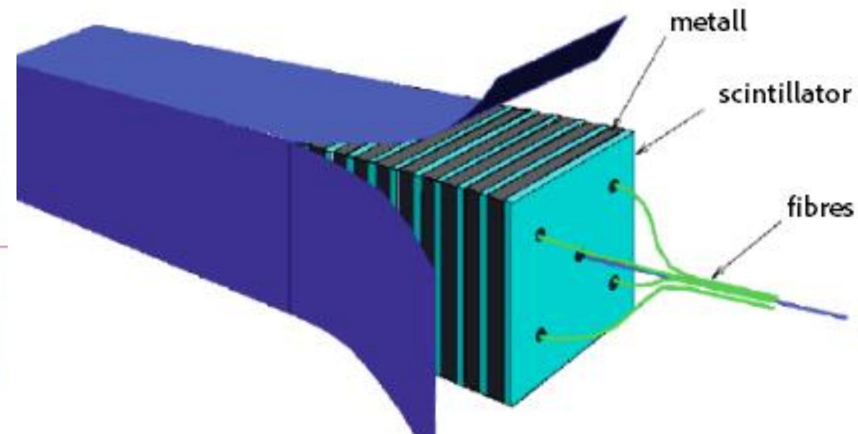
Electromagnetic calorimeter

- 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;
- Crystal variant is being considered, too.





About 6500 modules

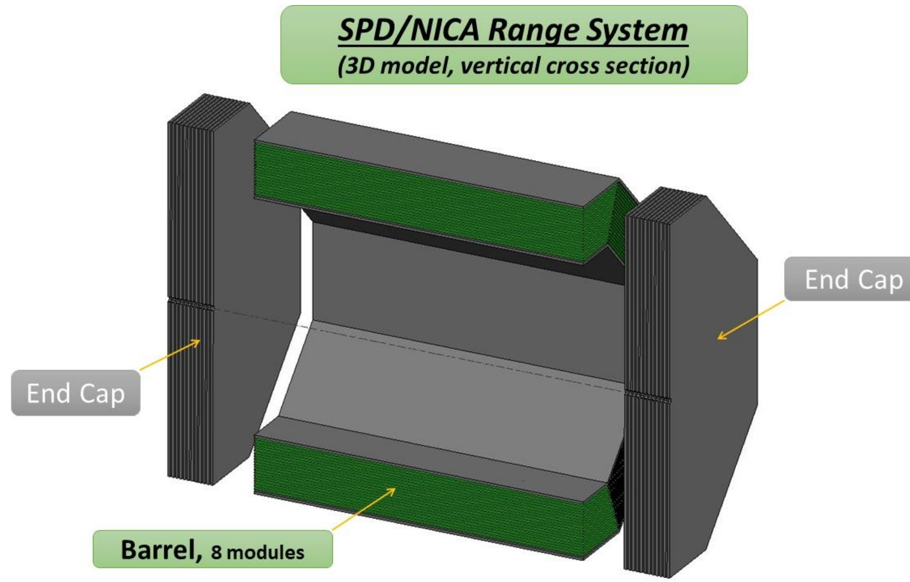


Shashlik

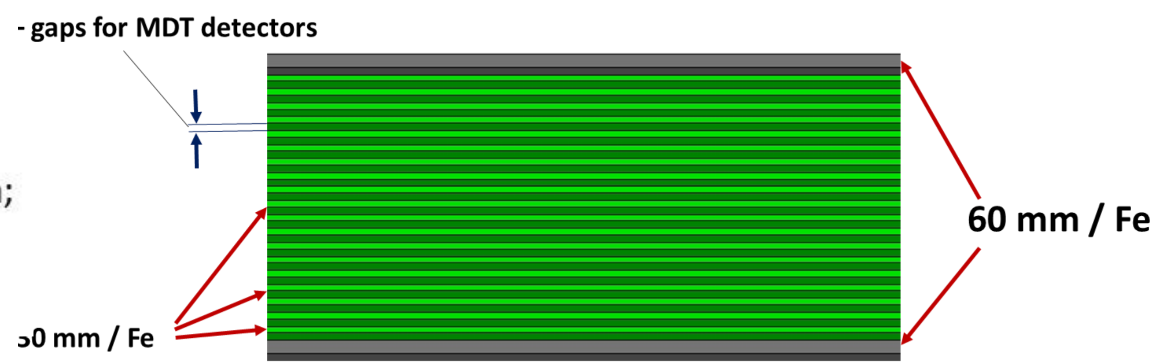
Range system

- It should provide good (~100%) muon identification for momenta above 1 GeV.
- Combination of responses from the ECal and RS could give additional lever for rejecting of pions and protons in a wide energy range.

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

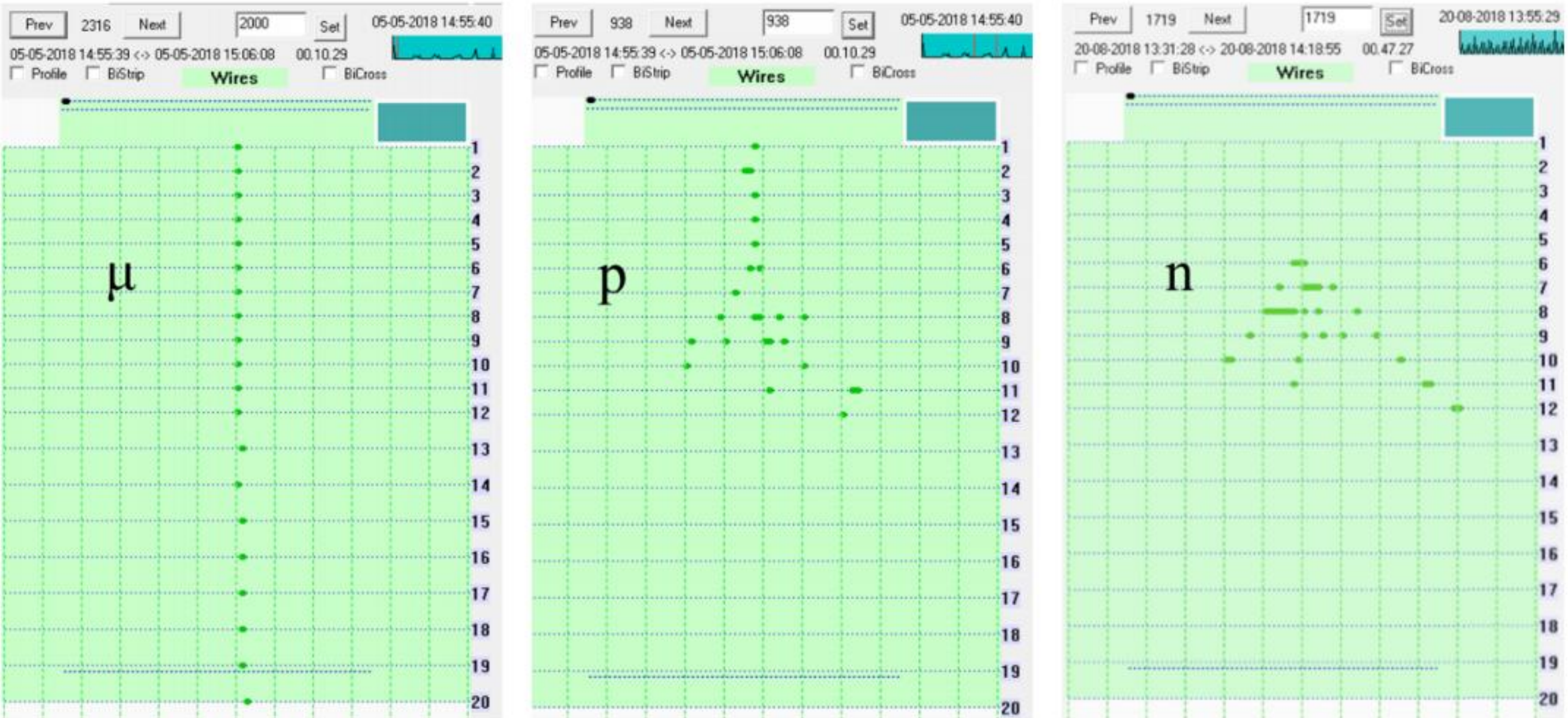


Barrel/Fe: 60+15x30+60 mm (3 λ i);
End Caps/Fe : 9x60 mm (2.8 λ i);
Air gaps = 35 mm; **L /barrel** = 8000 mm;
W = 1224.5 ton
Version : 09.2018



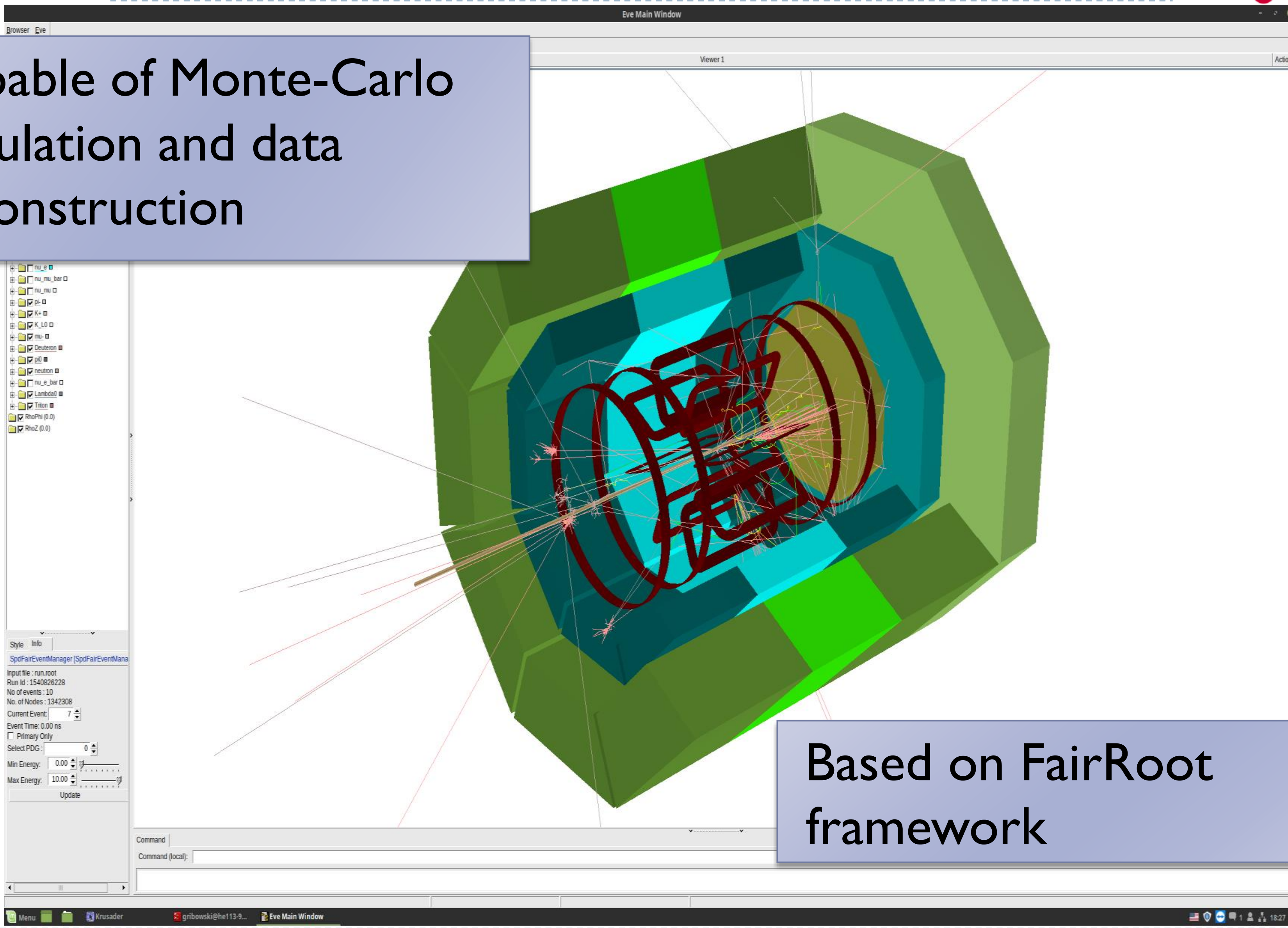
Hadrons identification in range system

P = 5.0 GeV/c. PANDA sample on test beam in CERN



We can identify hadrons in range system!

Software



Capable of Monte-Carlo simulation and data reconstruction

Based on FairRoot framework

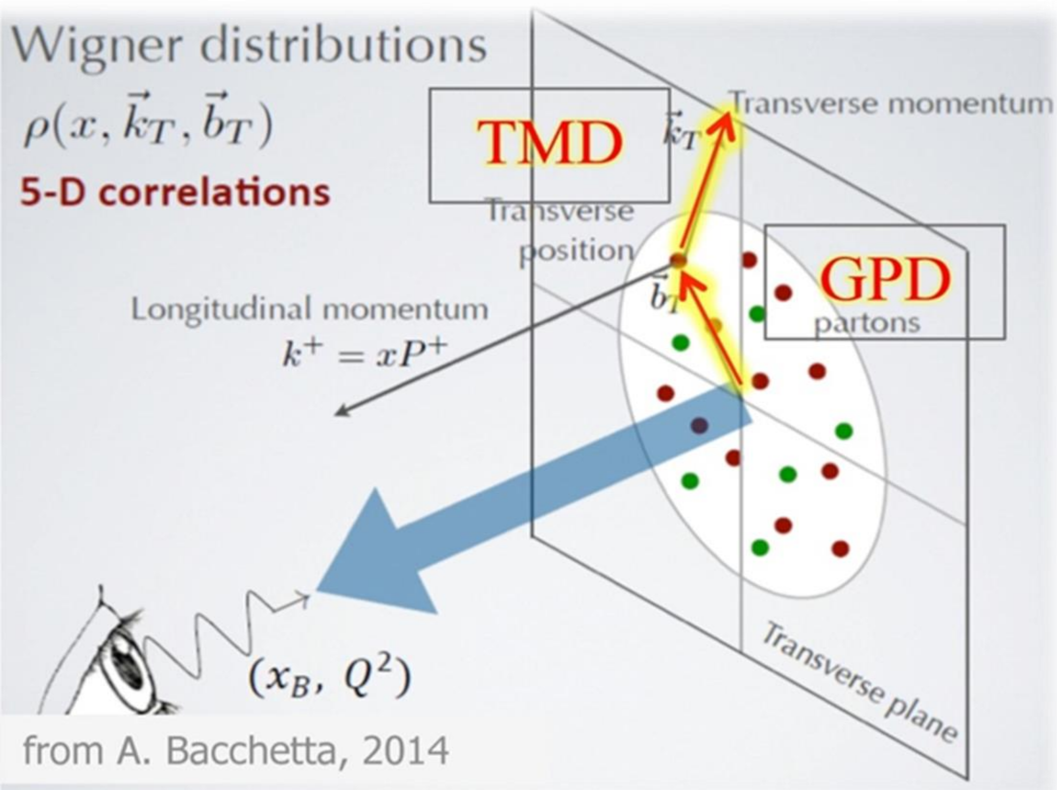
Plans

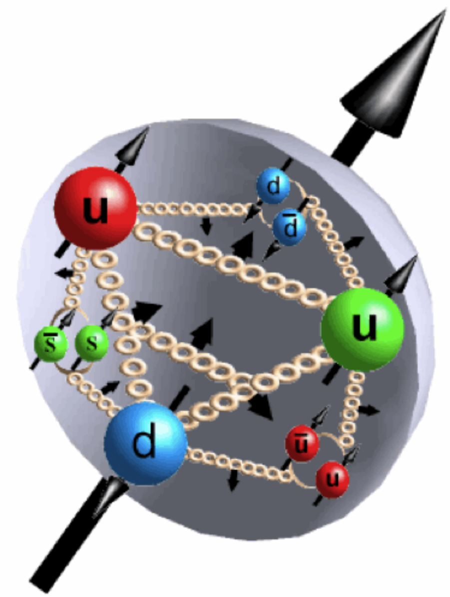
- Construction of the detector (2022-2025)
- First measurements – 2025…

You are welcome to join!

Thank you for your attention!

Backups



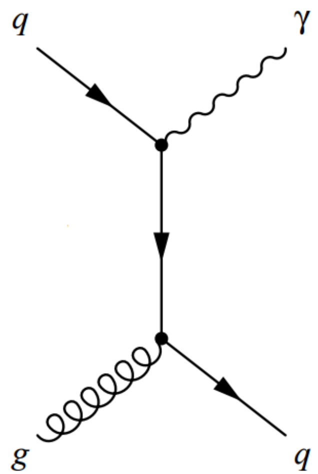


Transversity Momentum Distributions: TMD (x,k_T)
probe the transverse parton momentum dependence

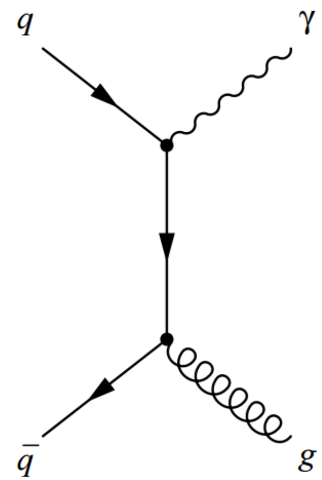
Generalized Parton Distributions : GPD (x,b_T):
probe the transverse parton distance dependence

Prompt photon production

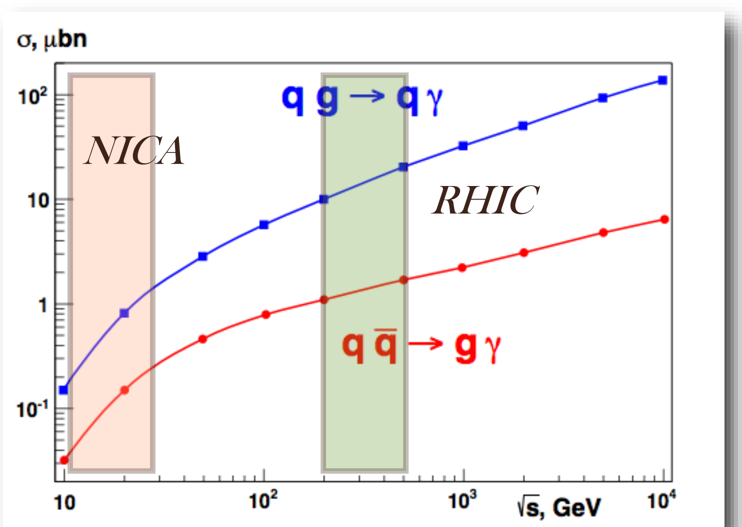
Gluon Compton scattering

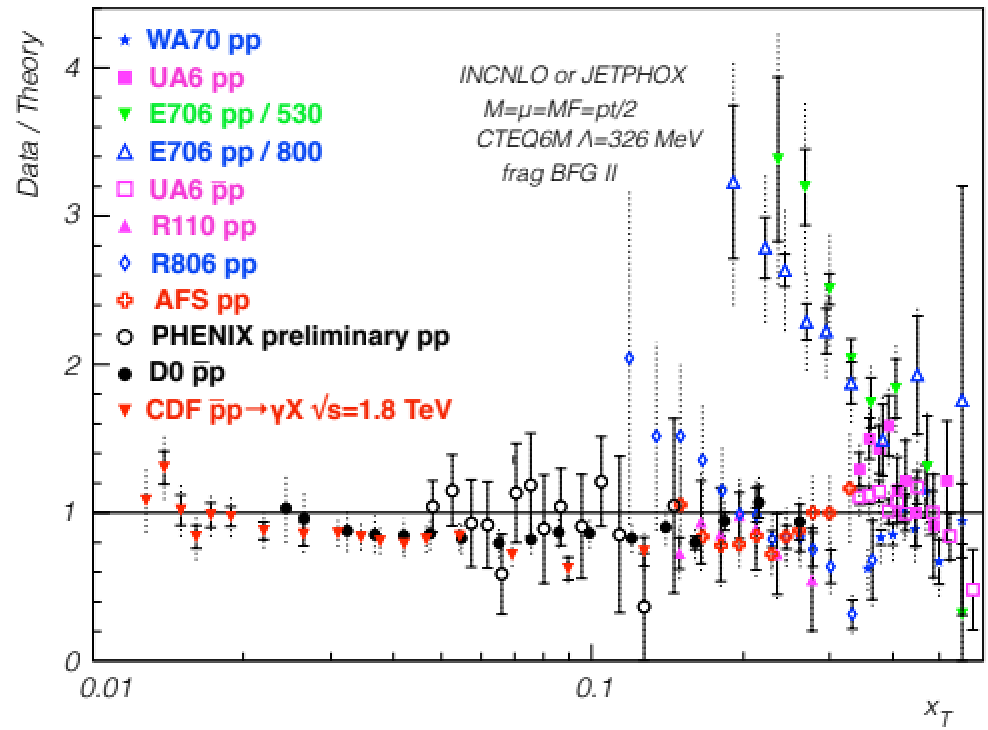


Quark-antiquark annihilation



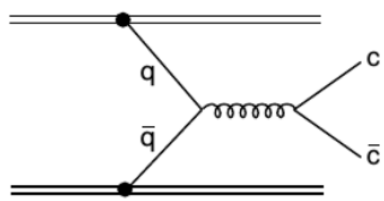
The gluon Compton scattering gives access to the gluon content of proton



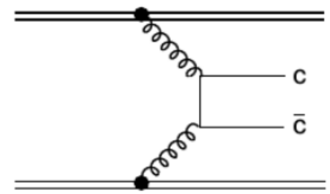


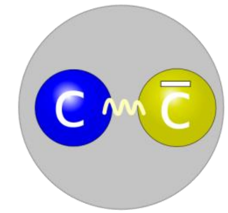
Charmonium production

Quark annihilation



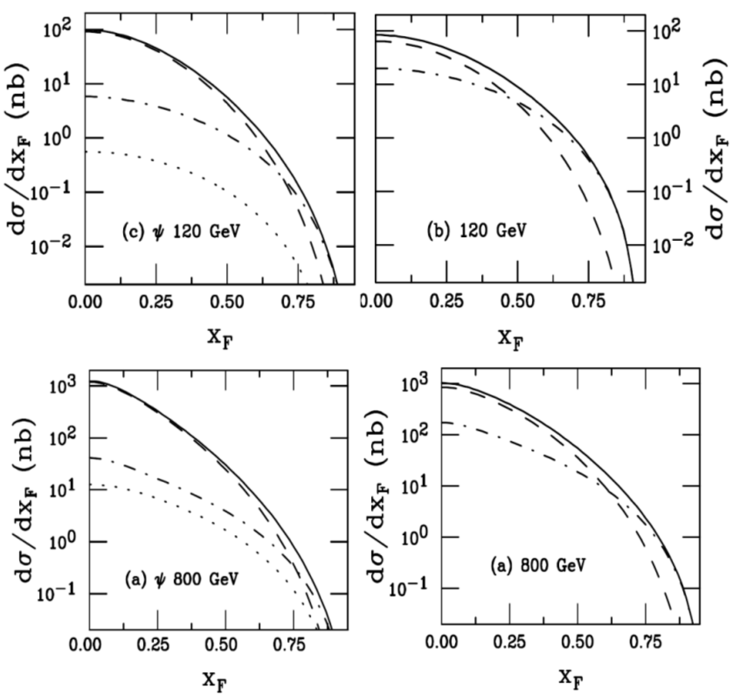
Gluon fusion

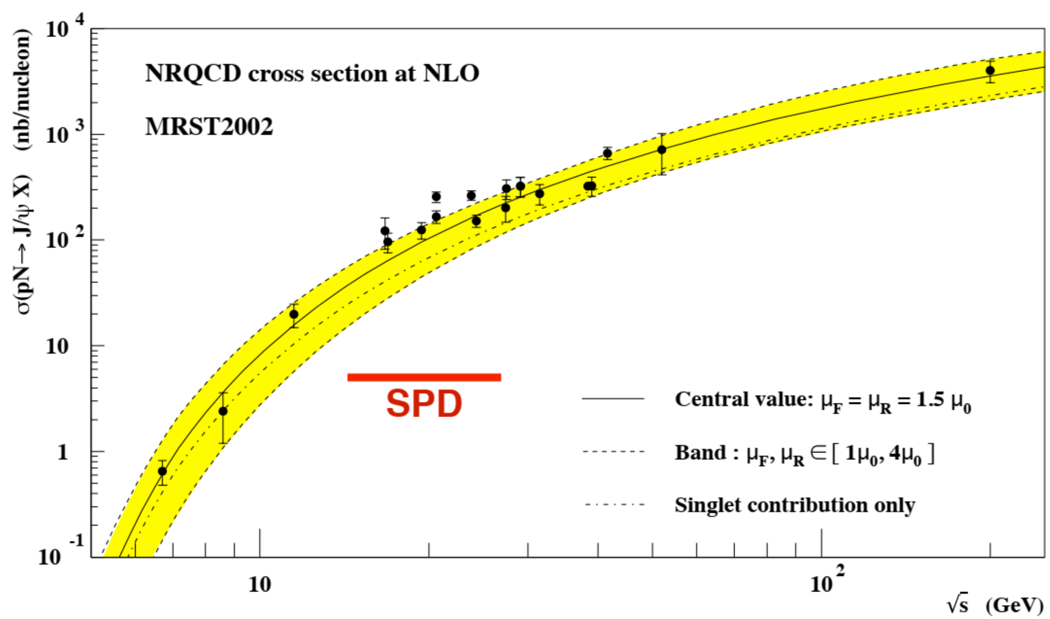




NRQCD

CEM

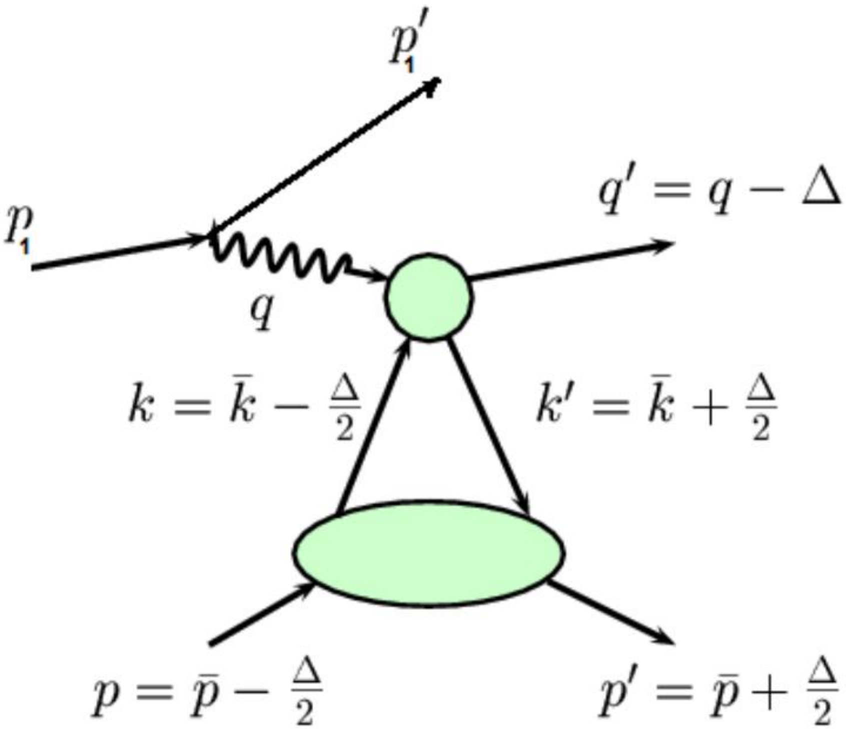


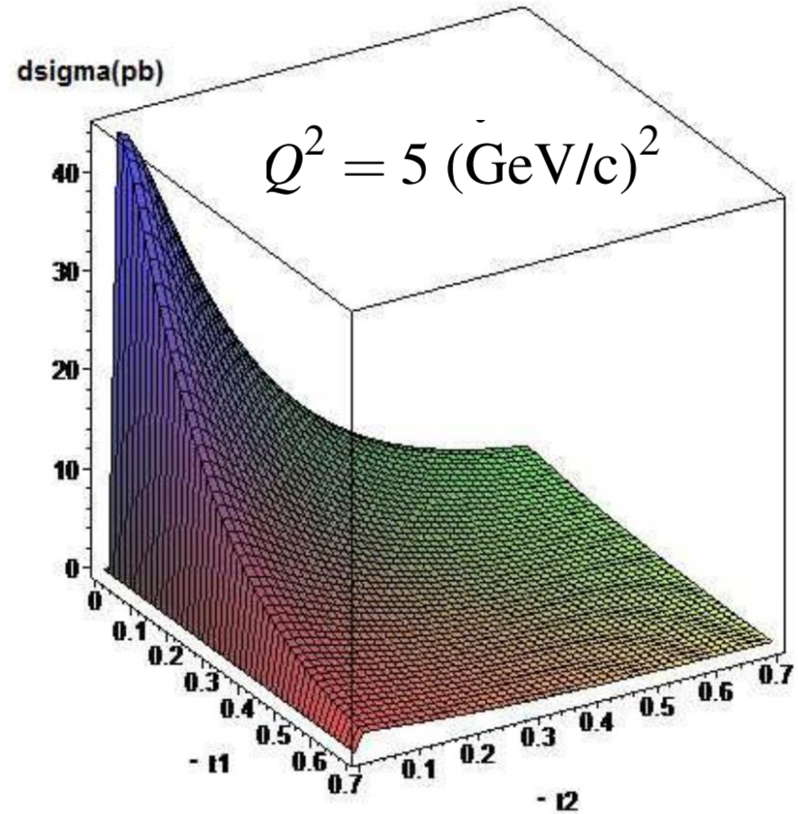


GPD through vector meson exclusive production

Exclusive DY

p+p → p+p+VM

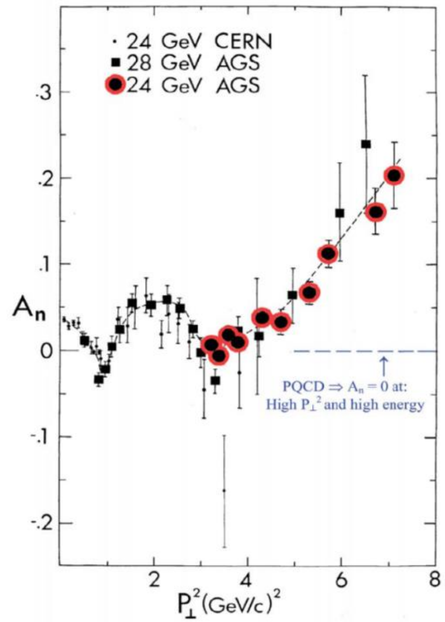


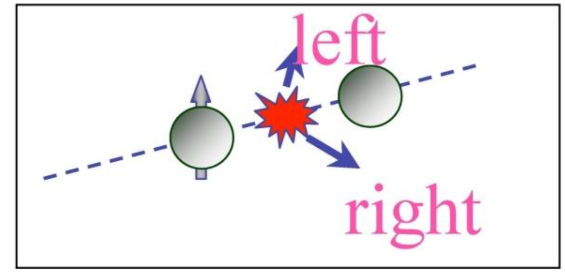


Vector meson production
via photoproduction mechanism or odderon exchange.

Asymmetries in high pT hadron production

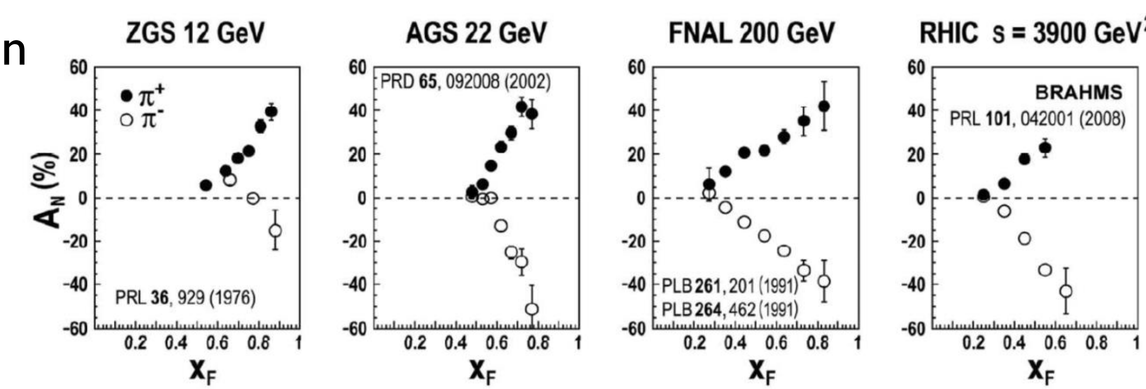
- Diquark properties;
- Confinement laws;
- Nature of the huge spin effects;
- Deuteron spin structure;
- Properties of the bare NΛ- and NK-interactions;
- Nature and properties of the cold super dense baryonic matter (CsDBM) (pA and AA);
- Dilepton production puzzle in np-interaction.





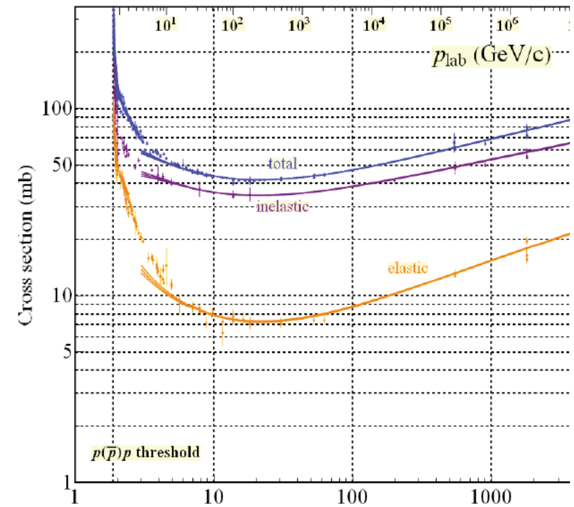
INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

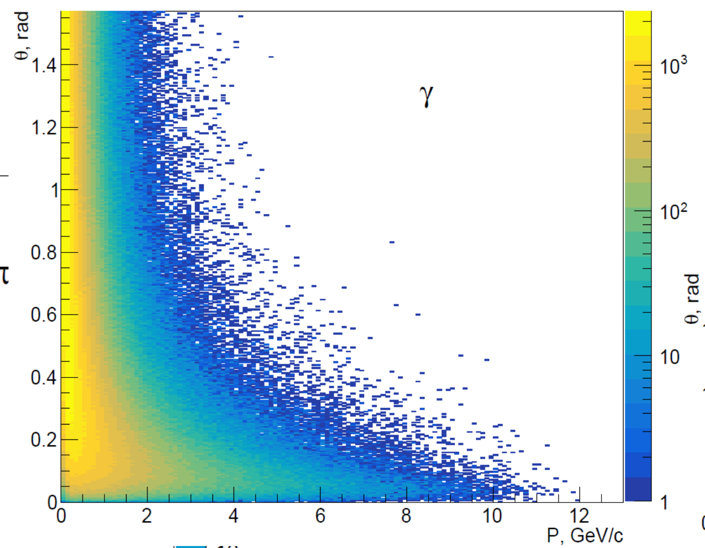
C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009

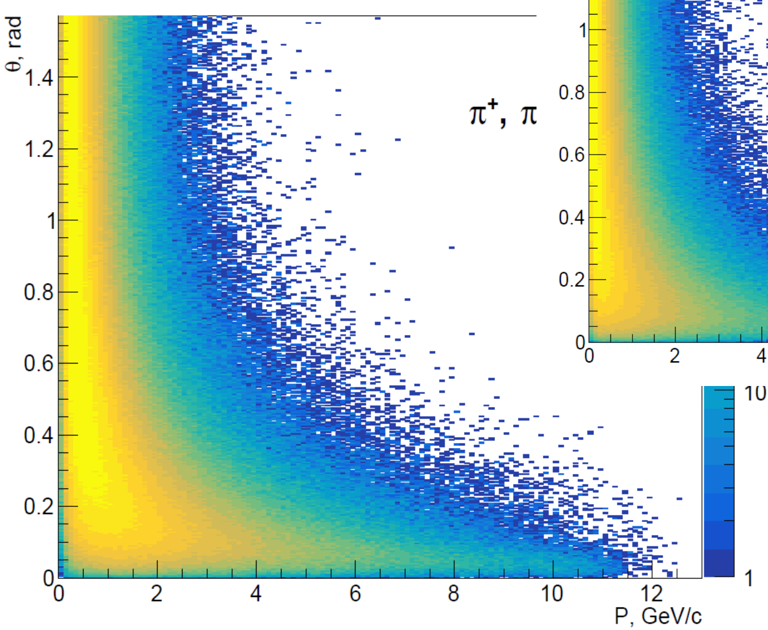


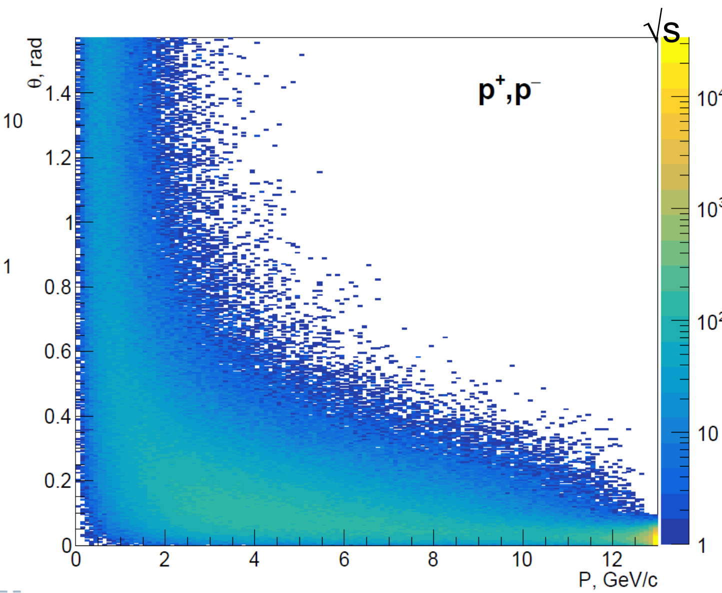
PYTHIA 6, $\sqrt{s_{pp}}$ = 26 GeV; 4 MHz event rate

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



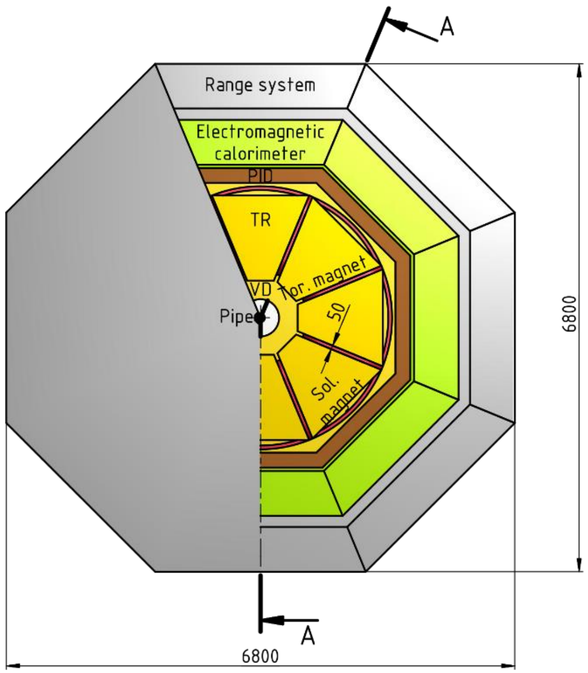




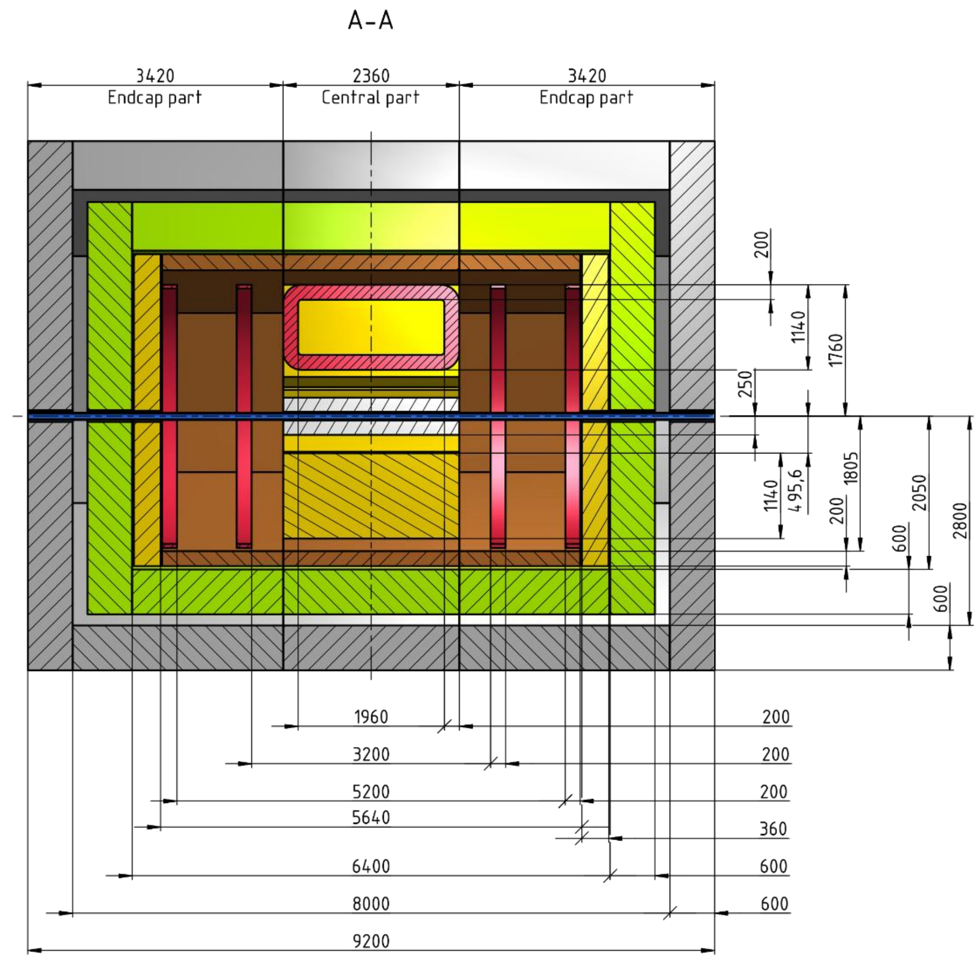


from A. Guskov

Dimensions



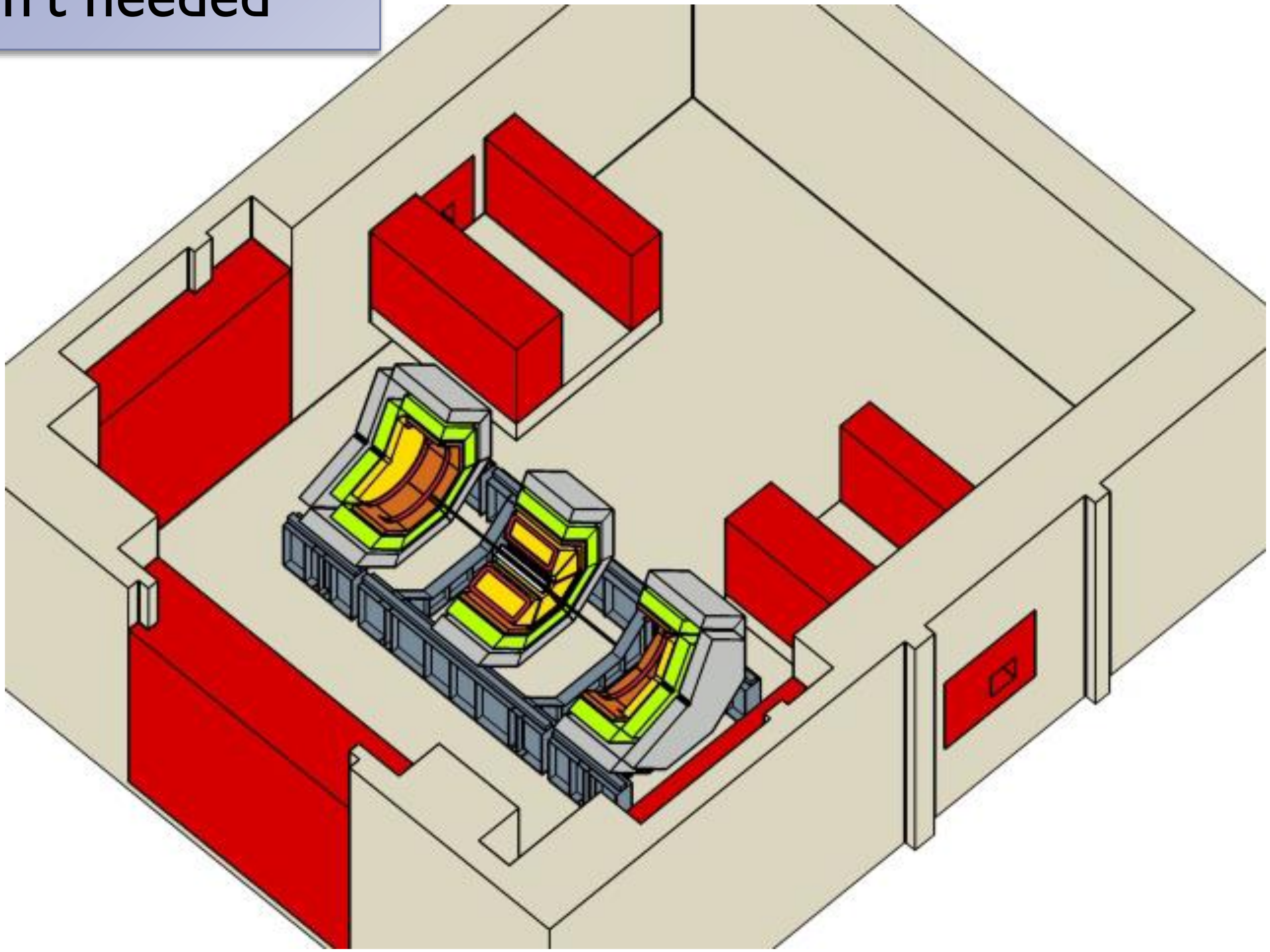
A
Range system
Electromagnetic
calorimeter
PID
TR
VD
Tor. magnet
Pipe
50
Sol.
magnet
6800
A
6800



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

Reconfigurable design

Can be removed from the beam and reconfigured in cases when toroidal magnet doesn’t needed



- Zero degree system;
- Front-end electronic;
- System for particle ID.