Feasibility of Drell-Yan measurements with SPD

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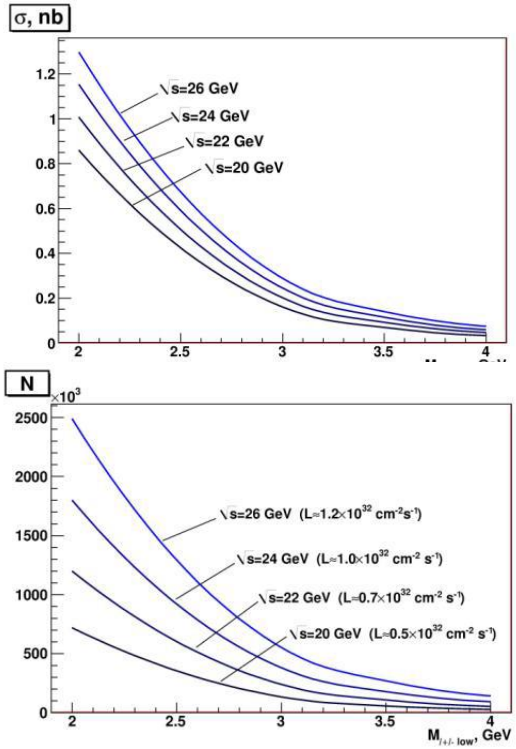
Estimations of DY pairs rates.

Estimation of the DY pair's production rate at SPD was performed using the expression for the differential and total cross sections of the pp interactions:

$$\frac{d^2\sigma}{dQ^2 dx_1} = \frac{1}{sx_1}\frac{4\pi\alpha^2}{9Q^2}\sum_{f,\bar{f}} e_f^2 [f(x_1,Q^2)\bar{f}(x_2,Q^2)]_{x_2=Q^2/sx_1}$$

$$\sigma_{tot} = \int_{Q^2_{min}}^{Q^2_{max}} dQ^2 \int_{x_{min}}^{1} dx_1 \frac{d^2\sigma}{dQ^2 dx_1},$$



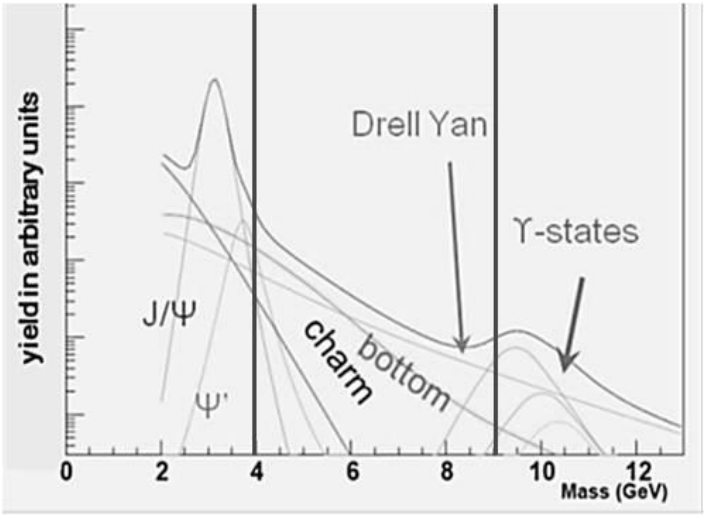
Cross section (left) and number of DY events (right) versus the minimal invariant mass of lepton pair for various proton beam energies

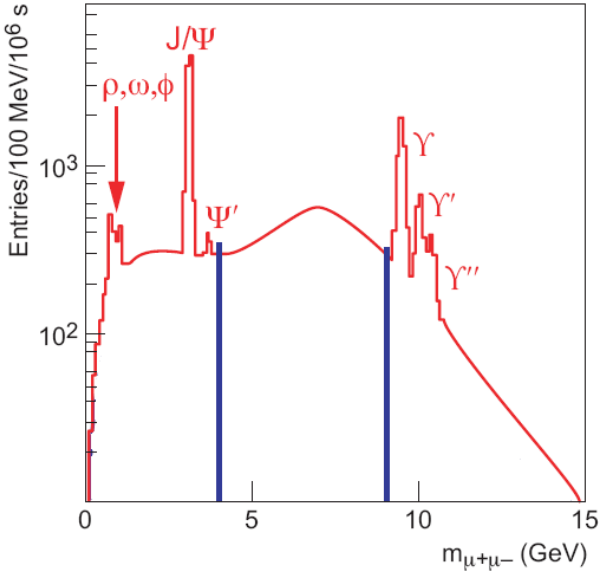
The Table shows values of the cross sections and expected statistics for DY events (K events) per four moths of data taking and 100% acceptance of SPD at two energies.

Lower cut on M_{l+l-}, GeV	2.0	3.0	3.5	4.0
$\sqrt{s}$=24 GeV (L = $1.0\cdot10^{32}$ cm^{-2} s^{-1})				
σ_{DY} total, nb	1.15	0.20	0.12	0.06
events	1800	313	179	92
$\sqrt{s}$=26 GeV (L = $1.2\cdot10^{32}$ cm^{-2} s^{-1})				
σ_{DY} total, nb	1.30	0.24	0.14	0.07
events	2490	460	269	142

Estimated DY and J/ψ statistics

Statistics of the J/Ψ and DY events (with cut on $M_{l\text{-}l+}$= *4 GeV*) expected to be recorded ("per year") in four months of data taking with 100% efficiency of SPD are given in Table.





$\sqrt{s}$, GeV	24	26	$\sqrt{s}$, GeV	24	26
$\sigma_{J/\psi} \cdot B_{e+e-}$, nb	12	16	σ_{DY} , nb	0.06	0.07
Events "per year"	$18 \cdot 10^6$	$23 \cdot 10^6$	Events "per year"	$92 \cdot 10^3$	$142 \cdot 10^3$

DY spectra with PYTHIA.

```
      PARP(2)=1.5d0     ! low limit c.m. energy
c---
      ckin(1)=1.0d0     ! ckin(1-2) range for m=sqrt(s)
      ckin(2)=-1.0d0    ! ckin(2), - inactive upper limit
c---
      MSEL=0                  ! turn OFF global process selection
      MSUB(1)=1                     ! turn ON q+qb -> gamma*/Z0 -> mu+mu- (DrellYan process)
      MSTP(43)=1                    ! only gamma* included (DrellYan process)
      MSTP(51)=4                    ! structure function for GRV 94L
      MRPY(1)=35476291              ! starting random number
      MDME(174,1)=0       ! Z0 -> dd~                   turned OFF
      MDME(175,1)=0       ! Z0 -> uu~                   turned OFF
      MDME(176,1)=0       ! Z0 -> ss~                   turned OFF
      MDME(177,1)=0       ! Z0 -> cc~                   turned OFF
      MDME(178,1)=0       ! Z0 -> bb~                   turned OFF
      MDME(179,1)=0       ! Z0 -> tt~                   turned OFF
      MDME(180,1)=0       ! Z0 -> b'b'~                 turned OFF
      MDME(181,1)=0       ! Z0 -> t't'~                 turned OFF
      MDME(182,1)=1       ! Z0 -> e+e-                  turned ON
      MDME(183,1)=0           ! Z0 ->nu_enu_ebar            turned OFF
      MDME(184,1)=0           ! Z0 -> mu+mu-                turned ON
      MDME(185,1)=0           ! Z0 -> nu_munu_mubar         turned OFF
      MDME(186,1)=0           ! Z0 -> tau+tau-          turned OFF
      MDME(187,1)=0           ! Z0 -> nu_taunu_taubar       turned OFF
      MDME(188,1)=0           ! Z0 -> tau'+tau'-        turned OFF
      MDME(189,1)=0           ! Z0 -> nu'_taunu'_taubar     turned OFF
      mstu(22)=1000  ! max number of errors that are printed
```

The distributions are obtained for 4π geometry, as well as for 4 variants of the muon pair detecting the working area of the SPD (preliminary design):

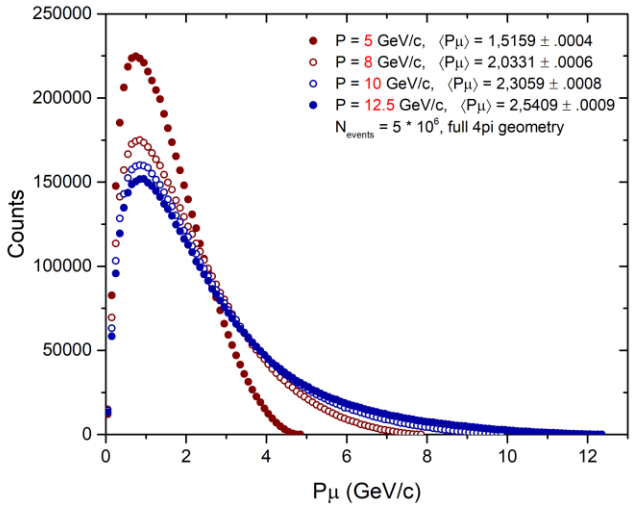
1.Central zone (R = 600 mm, L = ± 800 mm, minimum angle of muon $\theta\mu min$ = 36.9 deg.).

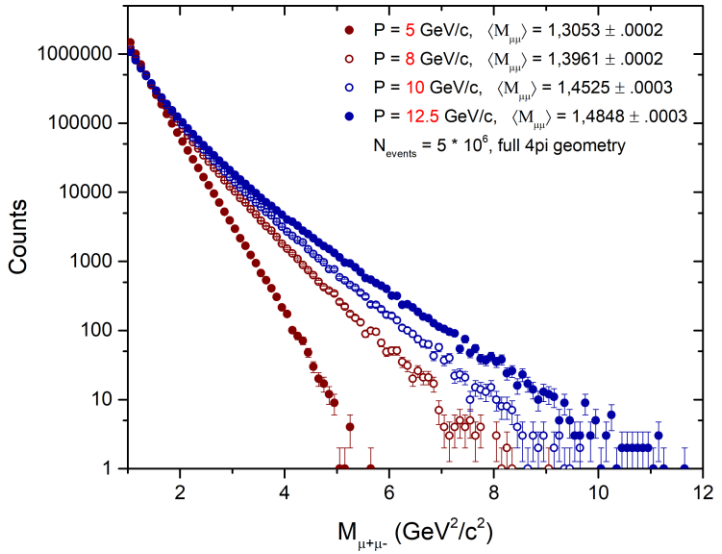
2. Electromagnetic calorimeter (R = 2050 mm, L = ± 2400 mm, minimum angle of muon $\theta\mu min$ = 40.5 deg.).

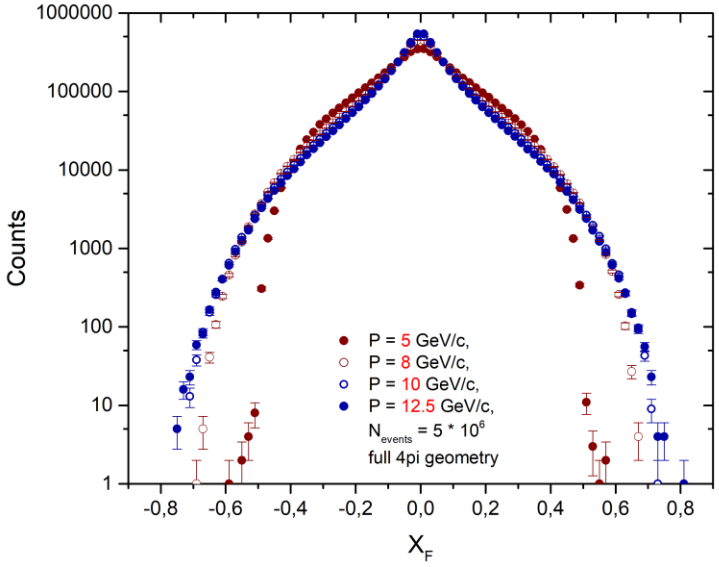
3. Range system (R = 2800 mm, L = ± 2400 mm, minimum angle of muon $\theta\mu min$ = 49.4 deg.).

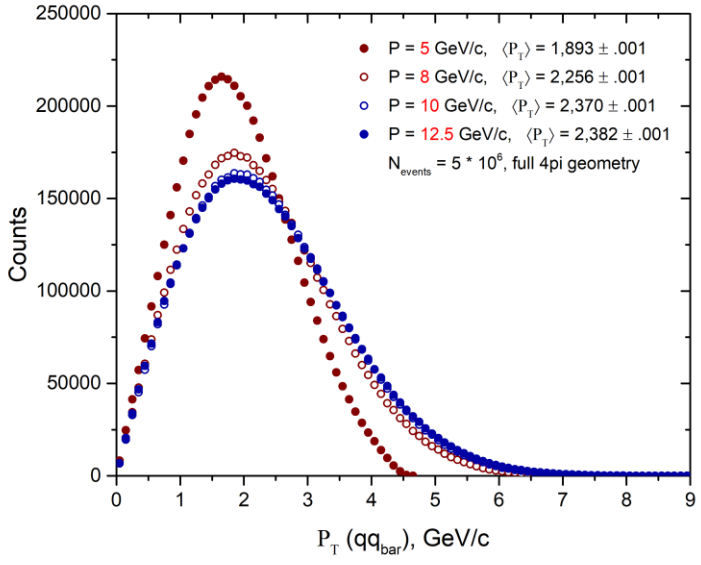
4. End Cap zone
(outside the Central zone, $3 < \theta\mu < 36.9$ deg.).

DY muons distributions (4pi).



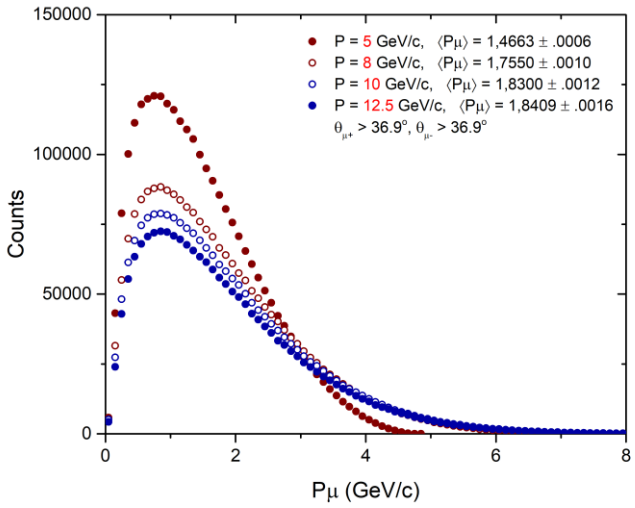


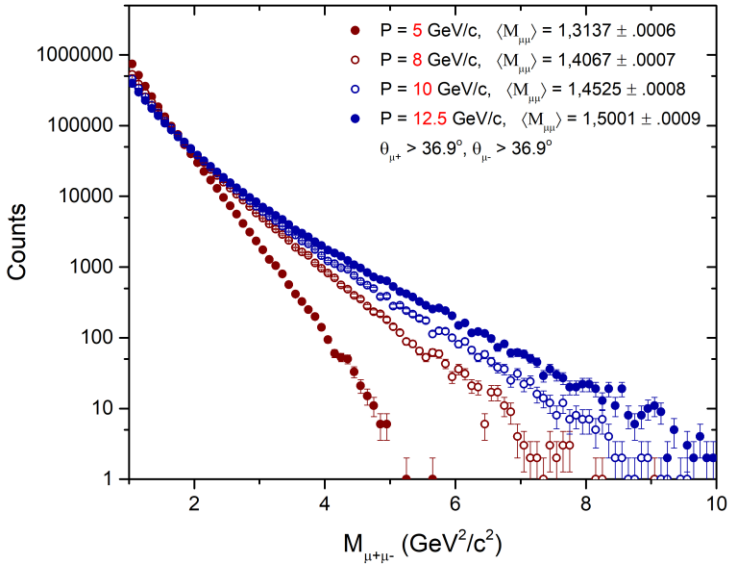


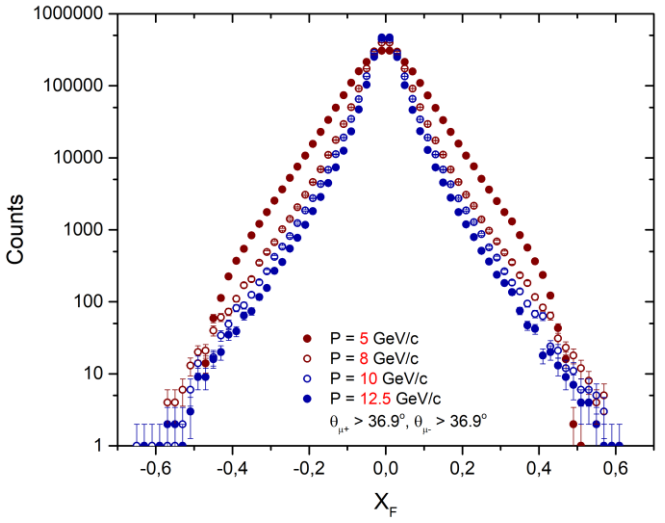


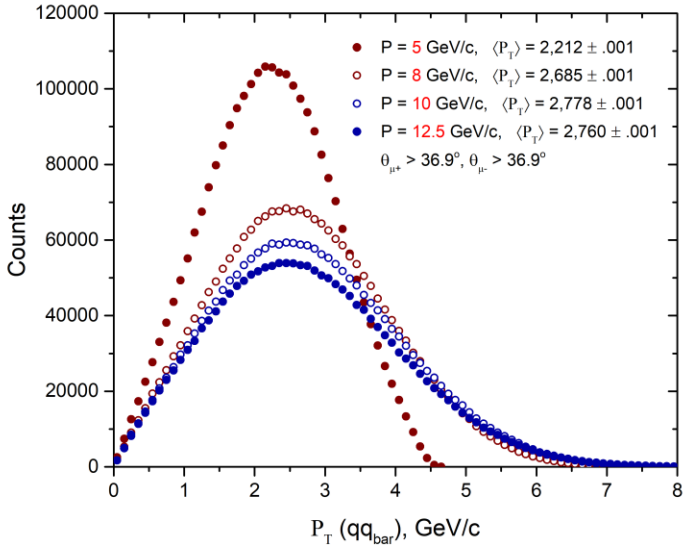
Plots are prepared by M.Kozhin

DY muons distributions (Central part).



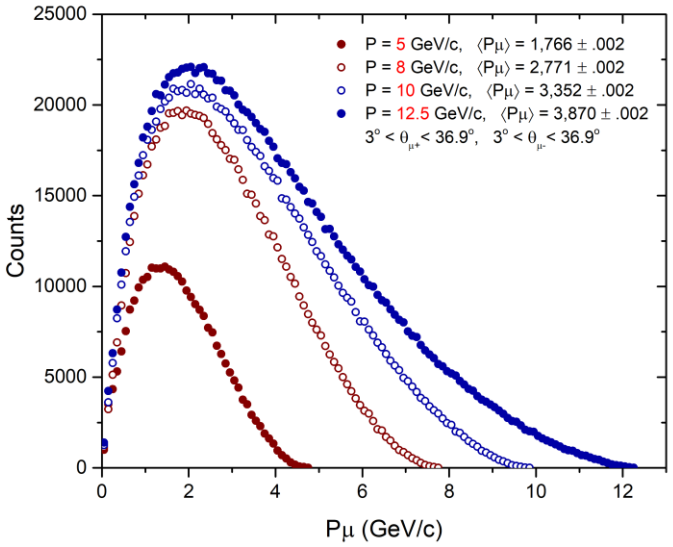


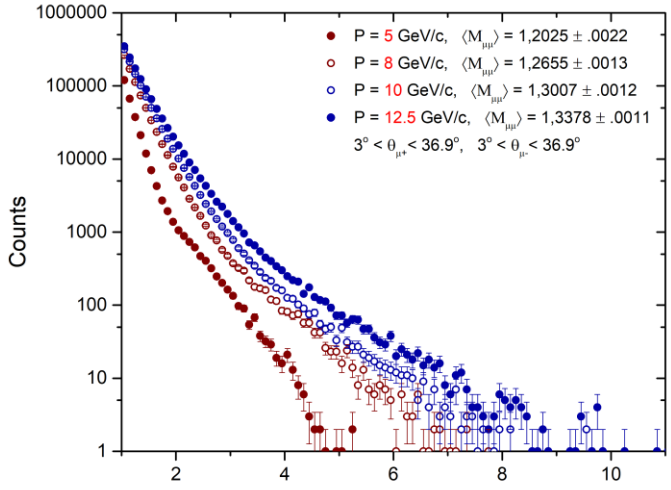


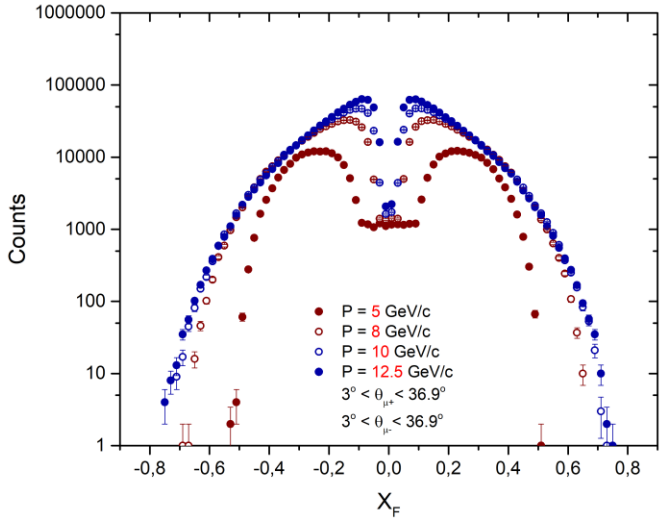


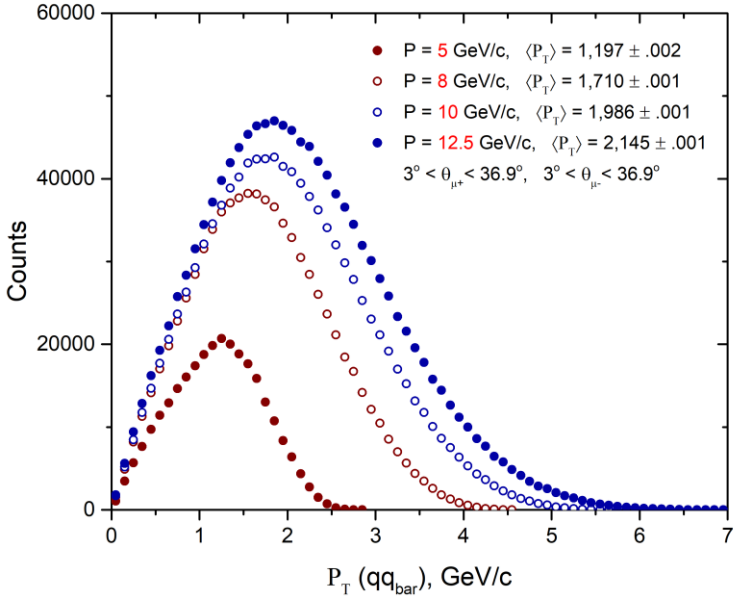
Plots are prepared by M.Kozhin

DY muons distributions (End caps).



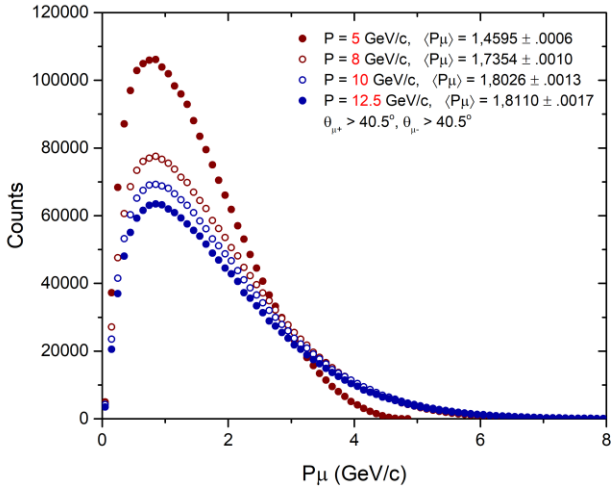


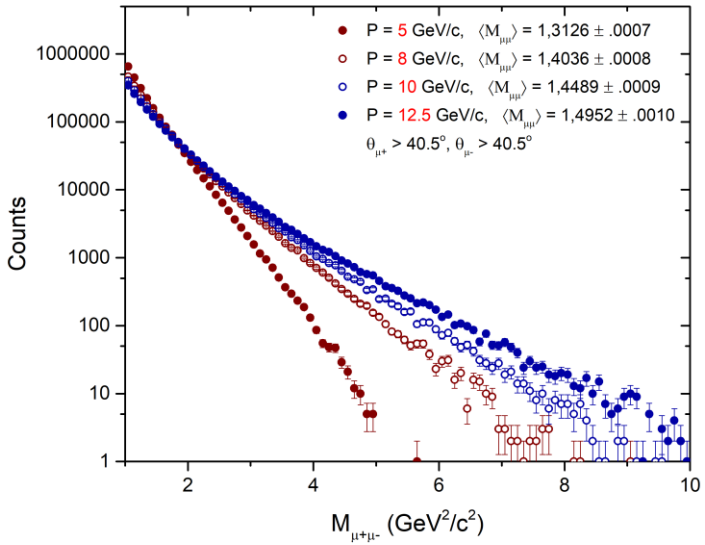


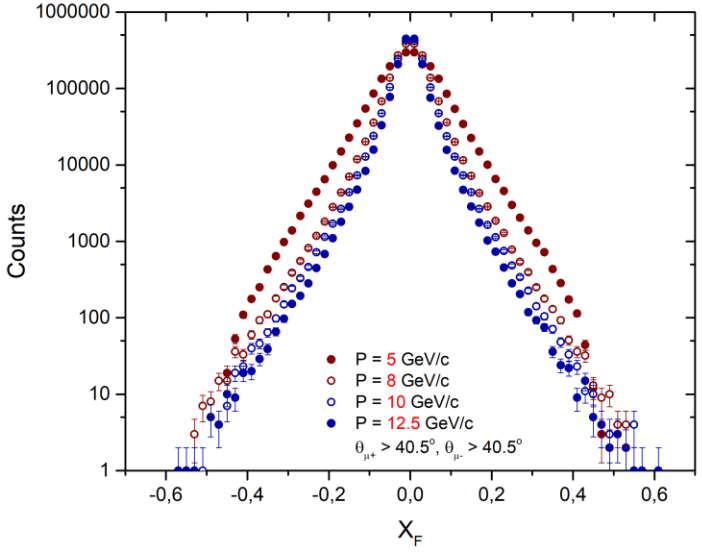


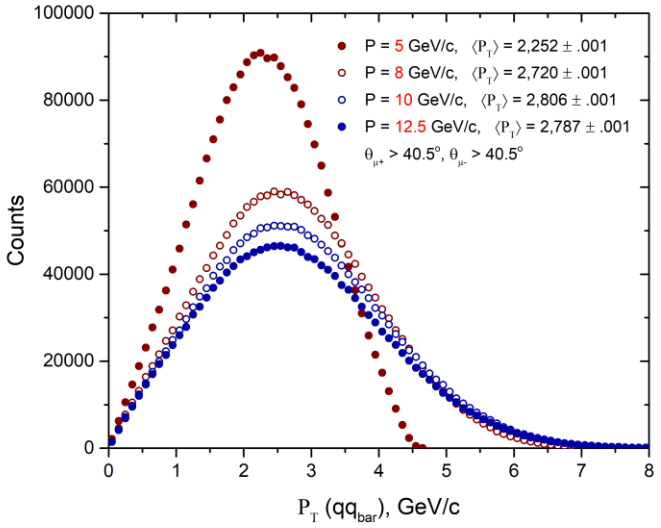
Plots are prepared by M.Kozhin

DY muons distributions (ECAL).



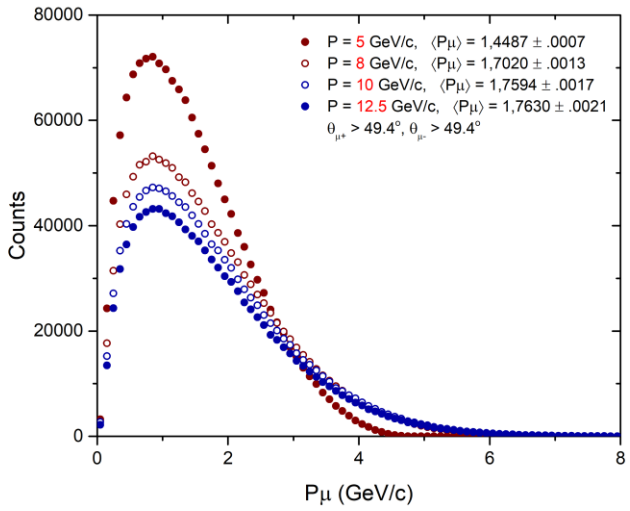


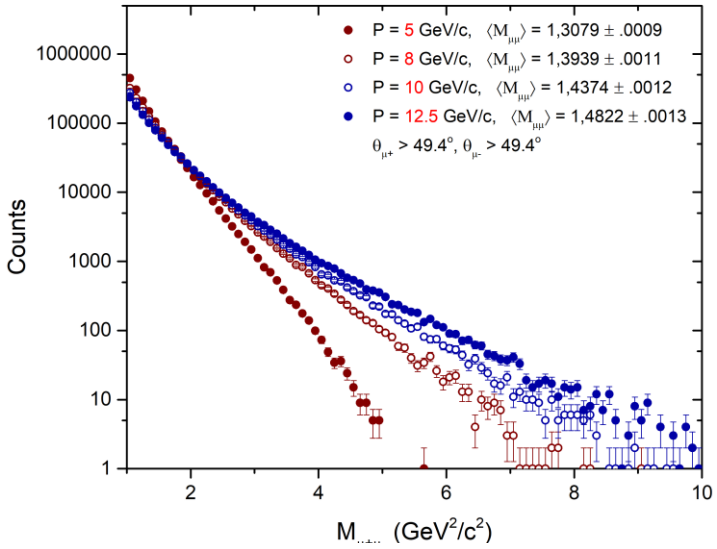


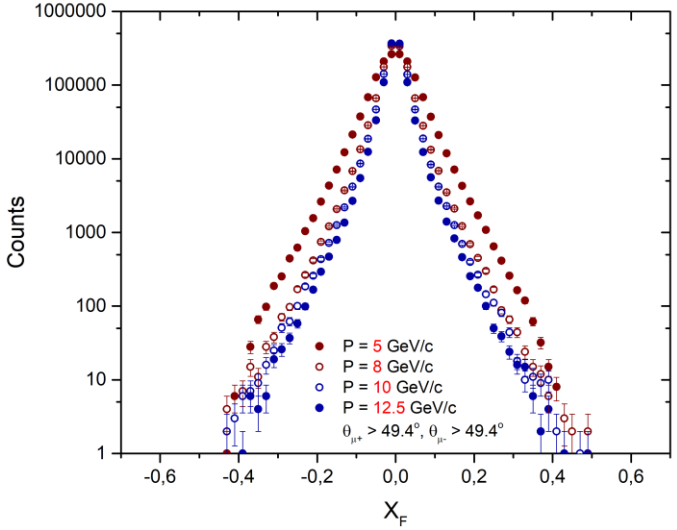


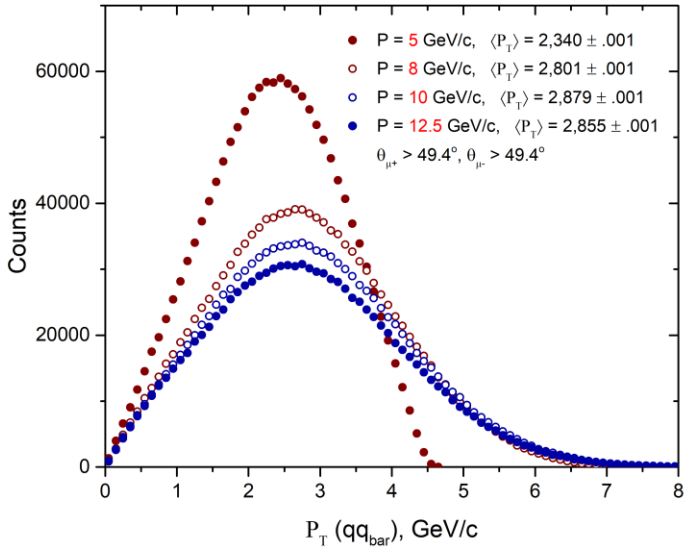
Plots are prepared by M.Kozhin

DY muons distributions (Muon system).









Plots are prepared by M.Kozhin

Extraction PDFs via asymmetries

Extraction of unknown (poor known) parton distribution functions (PDFs):

$p(D)p(D) \to \gamma^* X \to l^+ l^- X$ — **Boer-Mulders PDF**

$p^{\uparrow}(D^{\uparrow})p(D) \to \gamma^* X \to l^+ l^- X$ — **Sivers PDFs (Efremov,… PLB 612 (2005), PRD 73(2006));**

$p^{\uparrow}(D^{\uparrow})p^{\uparrow}(D^{\uparrow}) \to \gamma^* X \to l^+ l^- X$ — **Transversity PDF (Anselmino, Efremov, …)**

$p^{\uparrow}(D^{\uparrow})p(D) \to \gamma^* X \to l^+ l^- X$

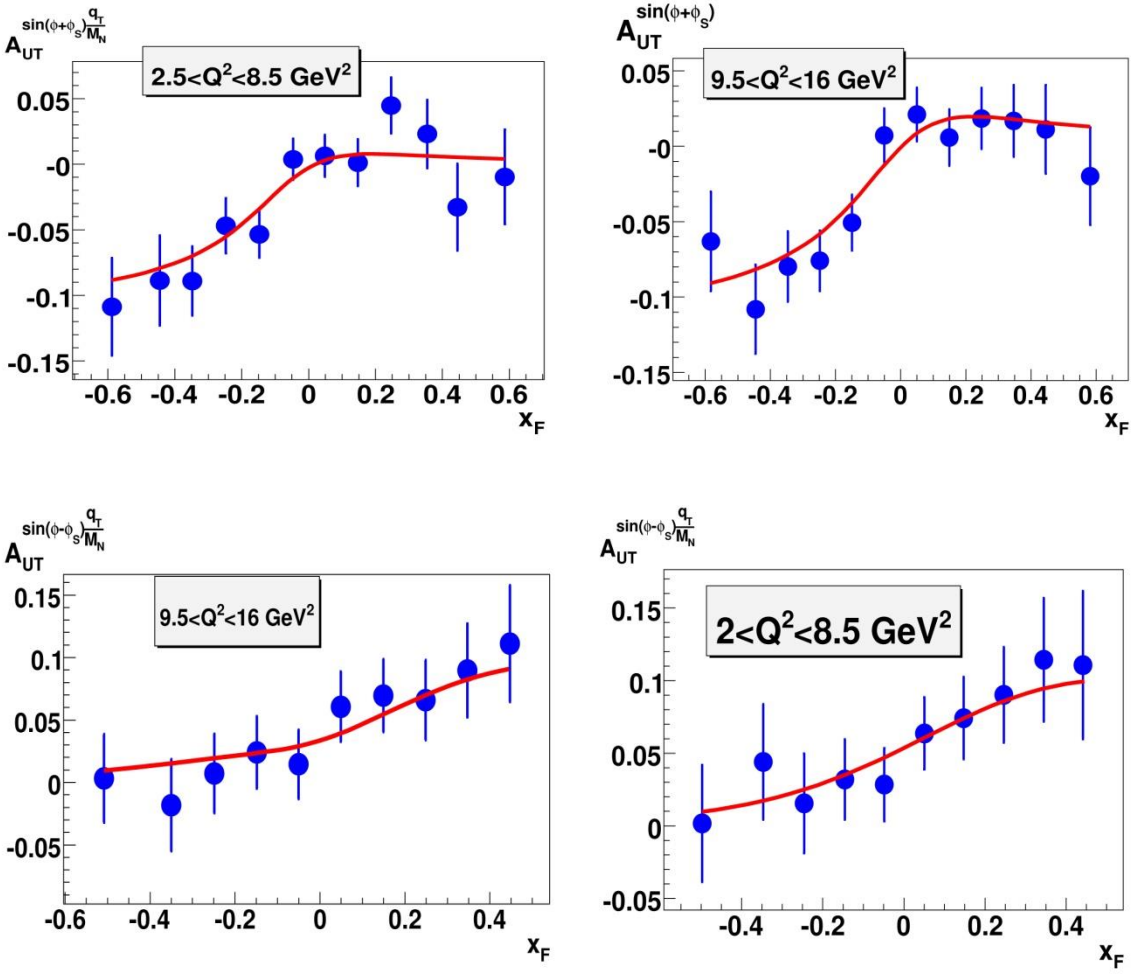
$p(D)p(D) \to \gamma^* X \to l^+ l^- X$

Transversity and first moment of Boer-Mulders PFDs (Sissakian, Shevchenko, Nagaytsev , Ivanov, PRD 72(2005), EPJ C46 ,2006 C59, 2009)

$p^{\rightarrow}(D^{\rightarrow})p^{\leftarrow}(D^{\leftarrow}) \to \gamma^* X \to l^+ l^- X$ — **Longitudinally polarized sea and strange PDFs and tenzor deuteron structure (Teryaev, …)**

The same PDFs from J/ψ production processes ($\sqrt{s} \le 10 GeV$).

Extraction PDFs via asymmetries



The set of original software packages (MC simulation, generator etc.) were developed for the feasibility studies of DY polarized processes.

A.Sissakian, et al., Eur. Phys. J. C46 (2006) 147, Eur.Phys.J. C59 (2009) 659-673, Phys.Part.Nucl. 41 (2010) 64-100

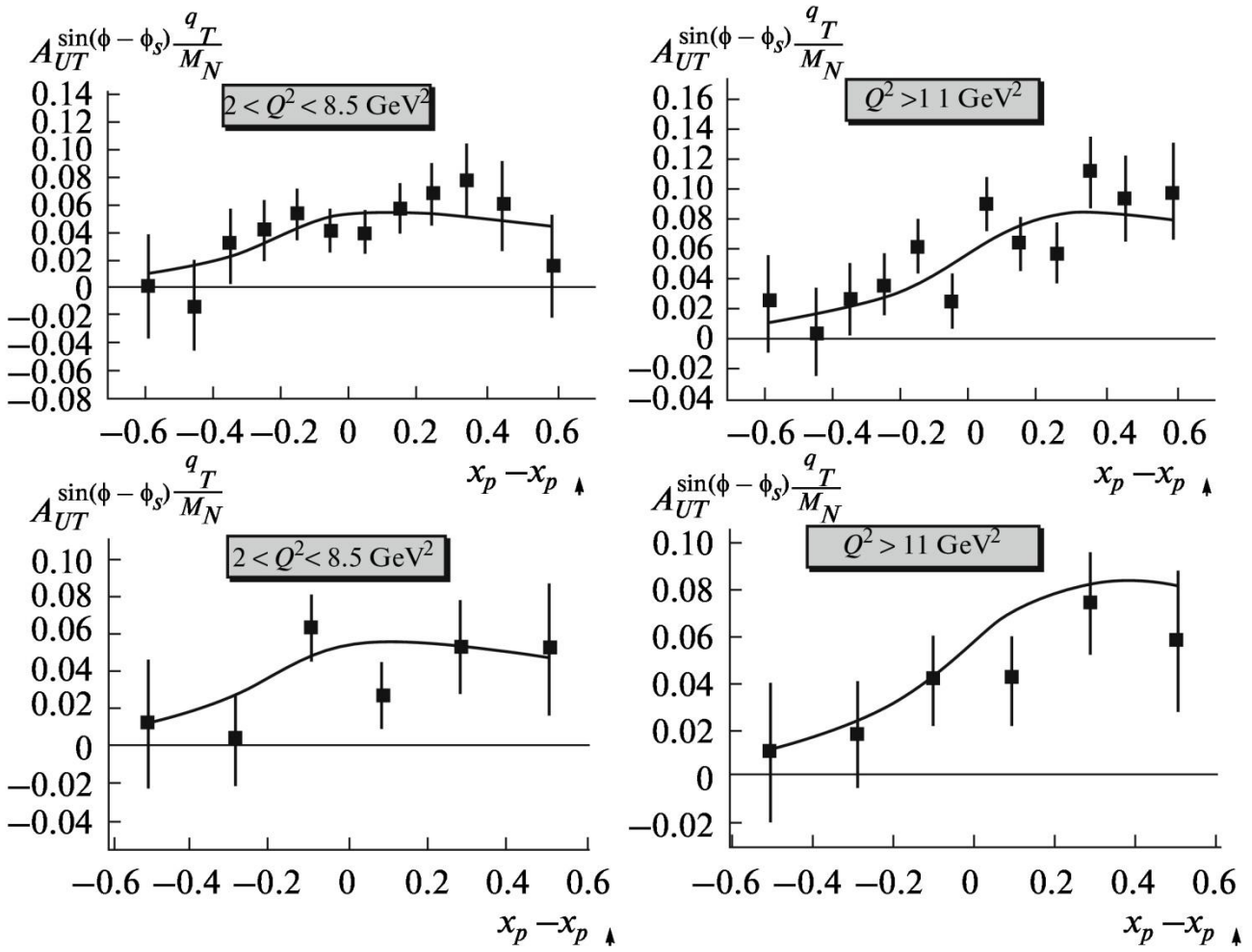
The SSA asymmetries.
Top:access to transversity and Boer-Mulders PDFs.
(Sissakian, Shevchenko, Nagaytsev,PRD 72 (2005), EPJ C46 (2006))

Bottom: access to Sivers PDFs

(Efremov,… PLB 612(2005), PRD 73(2006));

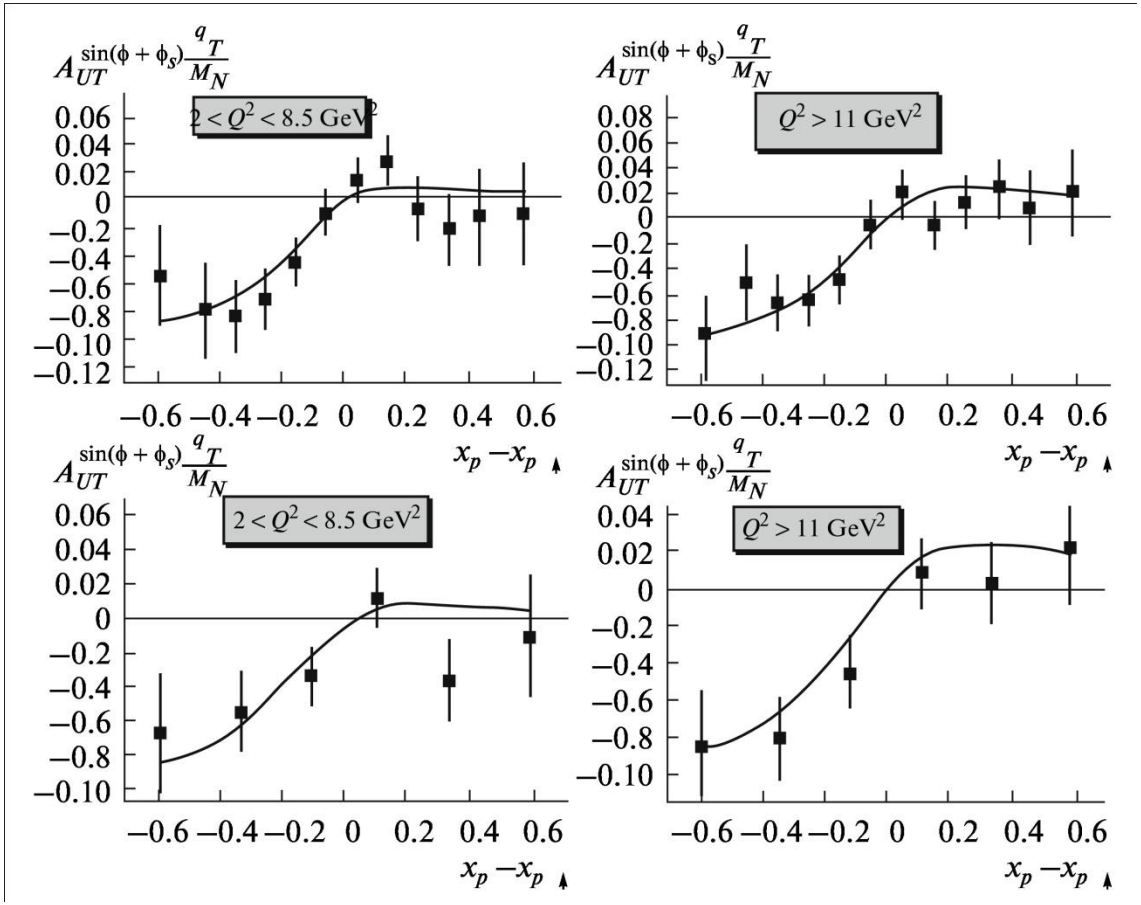
Alsymmetries are estimated for 100 K DY events

Extraction PDFs via asymmetries



Results of asymmetry simulation for NICA, *s = 400 GeV*^{2}. *Points* with error bars are obtained by simulation with polarized Drell–Yan event generator for statistics of (upper) 100000 and (lower) 50000 pure events; $\langle Q^2 \rangle$ *(left panels) 3.5 and (right panels) = 15 GeV*^{2}.

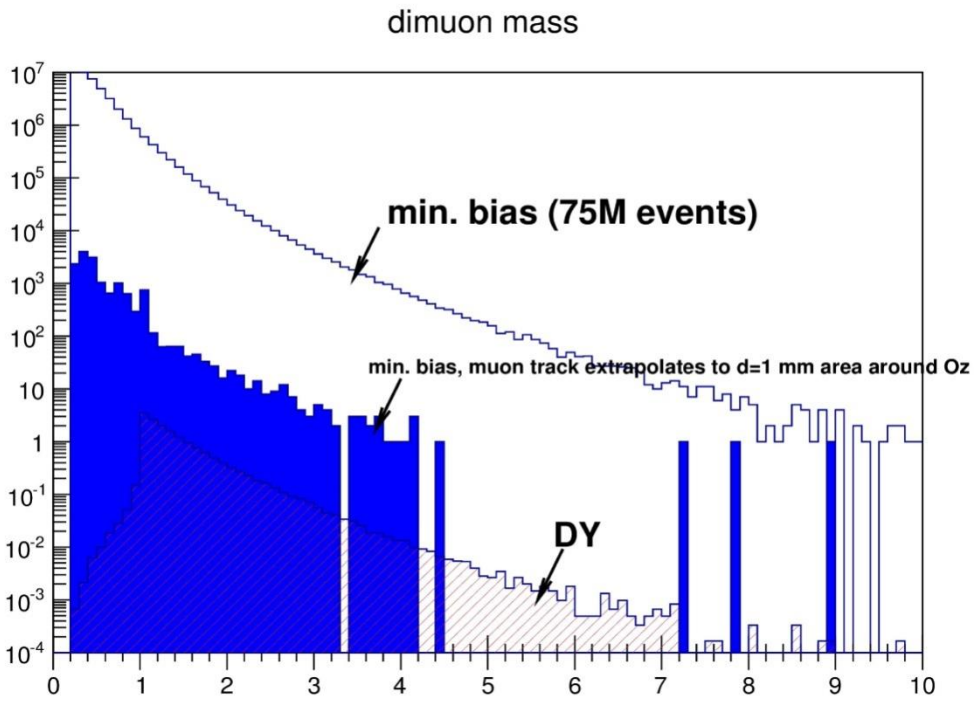
Extraction PDFs via asymmetries



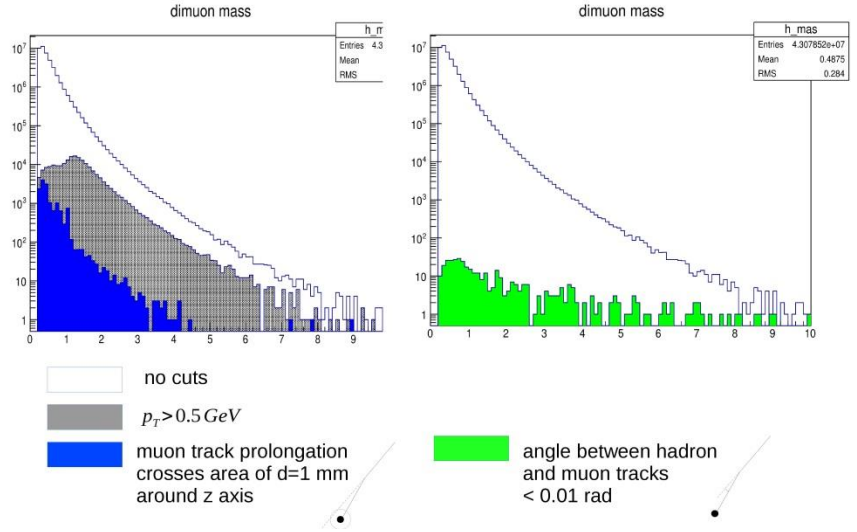
Results of asymmetry simulation for NICA, $s = 400$ GeV^2. *Parameterizations GRV94 and GRSV95 for q(x) and Δq(x), respectively, are used. Points with error bars are* obtained by simulation with polarized DY event generator for statistics of (upper) 100000 and (lower) 50000 pure events;
$\langle Q^2 \rangle$ (*left* panels) 3.5 and (right panels) = 15 GeV^2.

DY background studies (talk by R.Akhunzyanov)

- 2 proton beams with E=12 GeV
- Only process $q\bar{q} \rightarrow \gamma^* \rightarrow \mu^+\mu^-$
- $m_{\mu\mu} > 1\,GeV$
- Decays of $\pi^{\pm}, K^{\pm}, K^0_L$ turned on
- 10^5 events
- $\sigma_{tot} = 8.7\,nb$ (ratio $\sigma_{tot}(MB)/\sigma_{tot}(DY) \approx 4.5 \cdot 10^6$)
- Only muons produced in volume with L=8 m and D=7 m were taken into account.
- (For $m_{\mu\mu} > 3\,GeV$ $\sigma_{tot} = 0.23\,nb$)

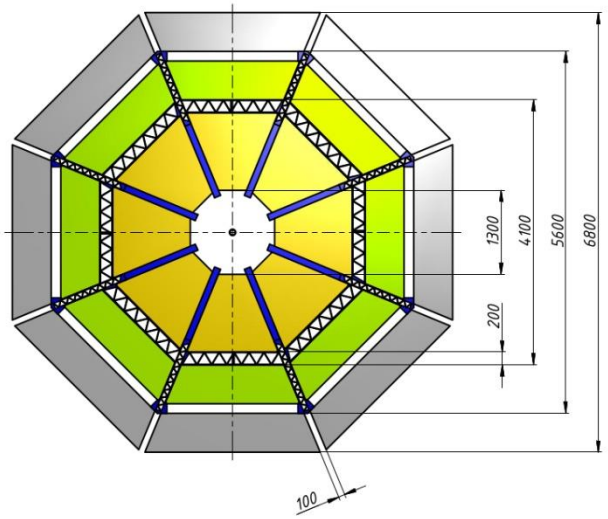


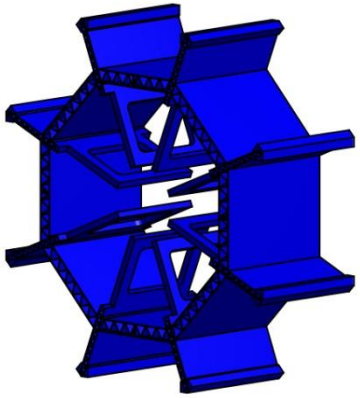
- PYTHIA 6
- MSEL=2
- 2 proton beams with E=12 GeV
- Decays of $\pi^{\pm}, K^{\pm}, K^0_L$ turned on
- $75 \cdot 10^6$ events
- $\sigma_{tot} = 39.4\,mb$

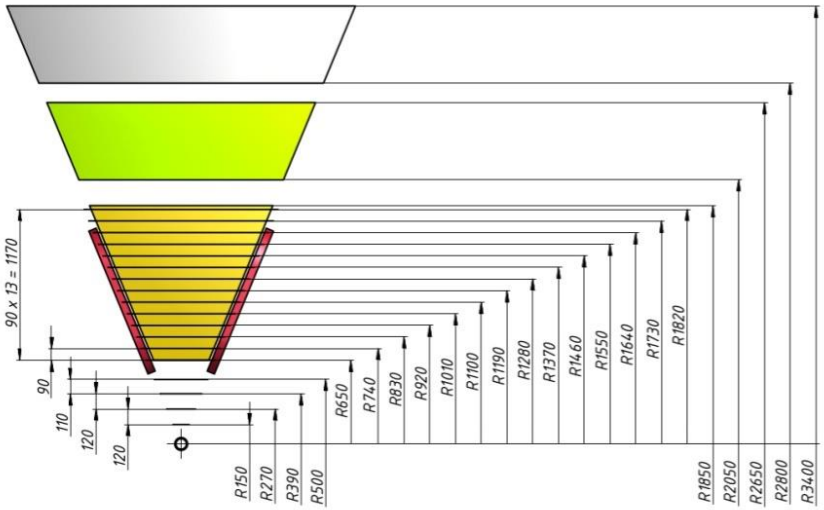


Tracking system has to be done with very high efficiency to reduce DY background.
OR use hadron absorber

DY background studies and central coordinate system (talk by A.Ivanov)







Радиус, мм	Длина, мм	Площадь, м2
150	1600	0,1491
270	1600	0,2684
390	1600	0,3877
500	1600	0,4971
650	6000	3,2309
740	6000	3,6782
830	6000	4,1256
920	6000	4,5729
1010	6000	5,0203
1100	6000	5,4676
1190	6000	5,9150
1280	6000	6,3623
1370	6000	6,8097
1460	6000	7,2570
1550	6000	7,7044
1640	6000	8,1517
1730	6000	8,5991
1820	6000	9,0464

The main tasks of the coordinate system: tracking charged particles (momentum definition) and reducing the background to DY from the decays of the pions (see talks by A.Ivanov and R.Akhunzyanov)

DY background studies and central coordinate system (talk by A.Ivanov)

The central coordinate plane. NA62 straw system

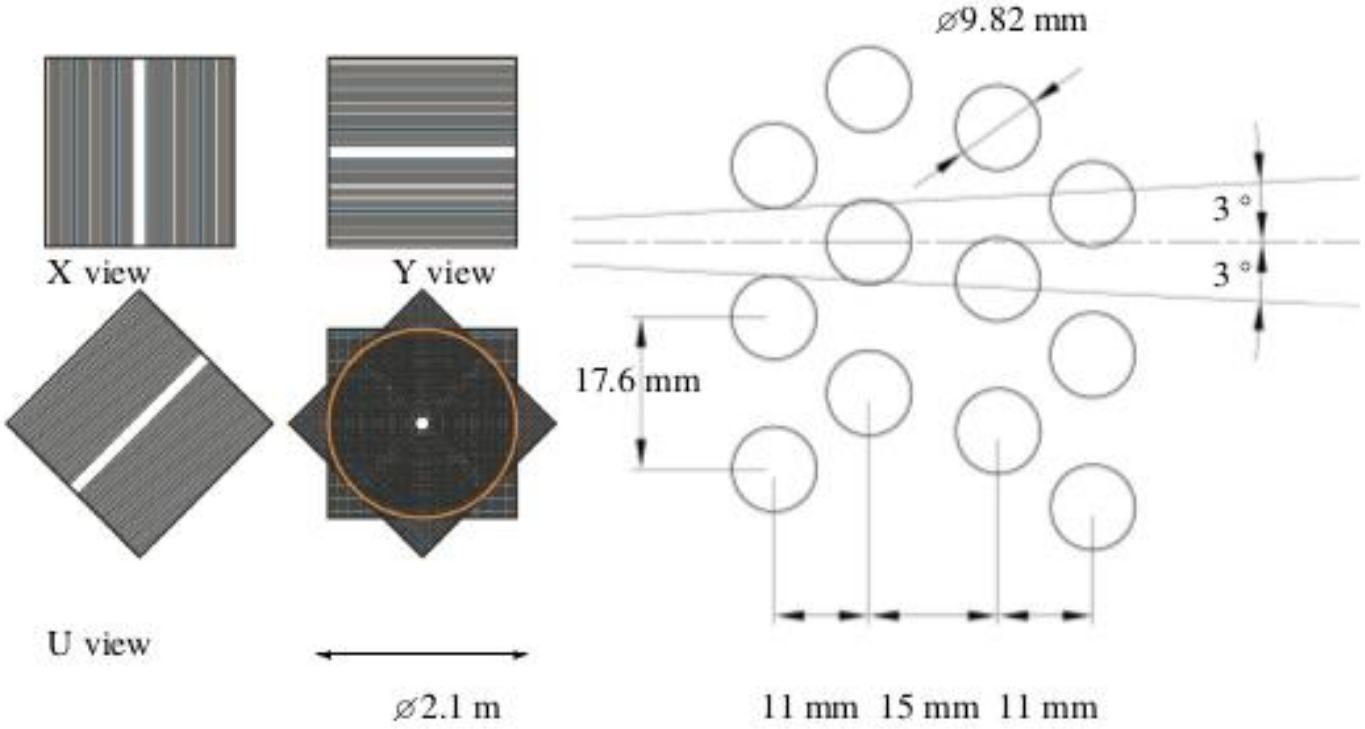
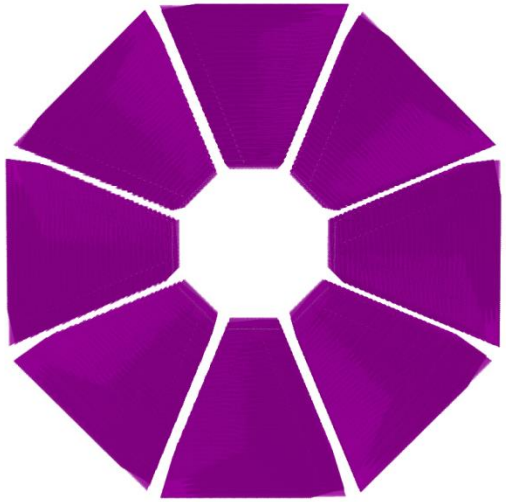
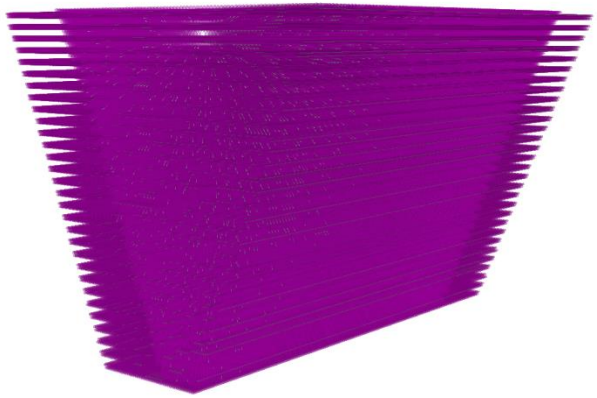


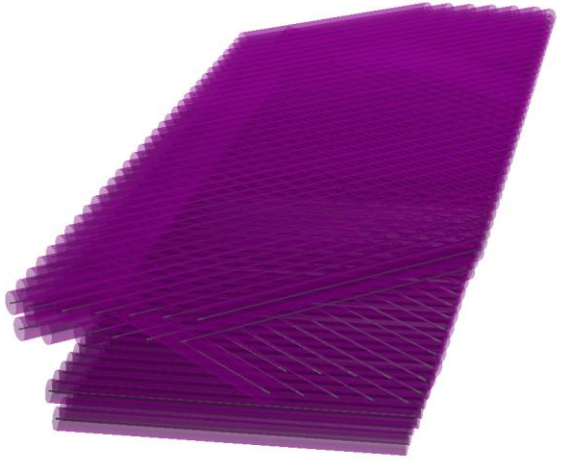
Figure 22. Left: one straw chamber is composed of four views (X, Y, U, V) and each view measures one coordinate. Near the middle of each view a few straws are left out forming a free passage for the beam. Right: the straw geometry is based on two double layers per view with sufficient overlap to guarantee at least two straw crossings per view and per track, as needed to solve the left-right ambiguity. The ± 3° angle corresponds to the angular range of tracks produced in kaon decays and detected within the geometrical acceptance of the spectrometer.

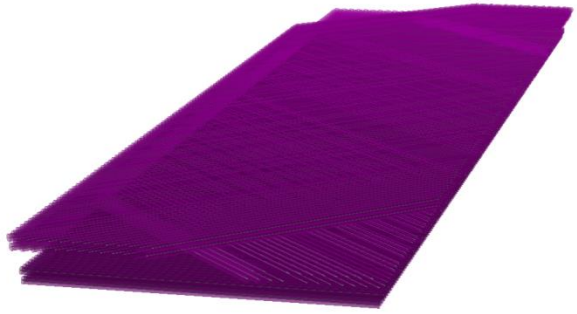
DY background studies and central coordinate system
(talk by A.Ivanov)





The special MC SPD tool to optimize Coordinate system was developed. Analysis is in progress. (see talk by A.Ivanov)





CONCLUSIONS

- DY measurements can be performed on the SPD under the condition of high luminosity, high degree of beams polarizations,

- Statistics of more than 50 K pure DY events will allow to obtain statistically significant results on asymmetries,

-The biggest problem is the background from decays of pions,

-The pion background can be decreased by absorber (under consideration) or with detecting pion decays by coordinate system (MC studies).

BACKUP SLIDES

DY muons distributions.