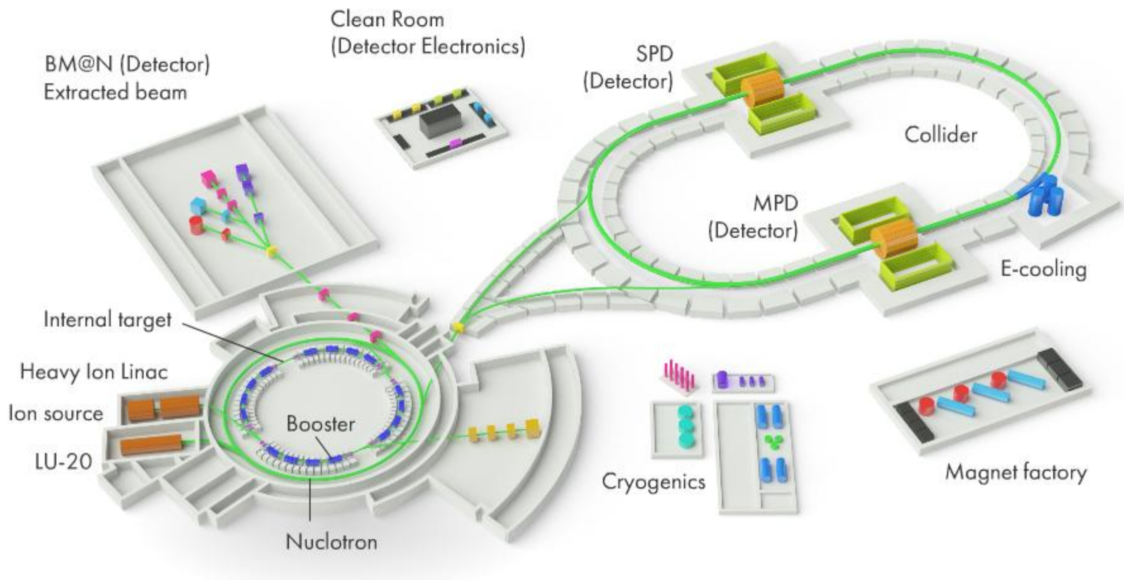
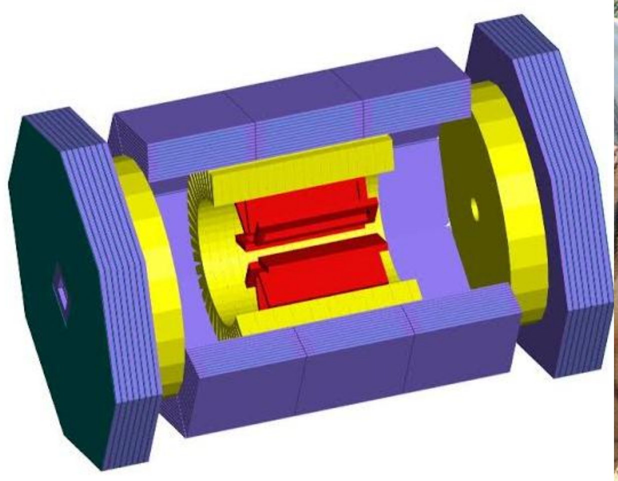
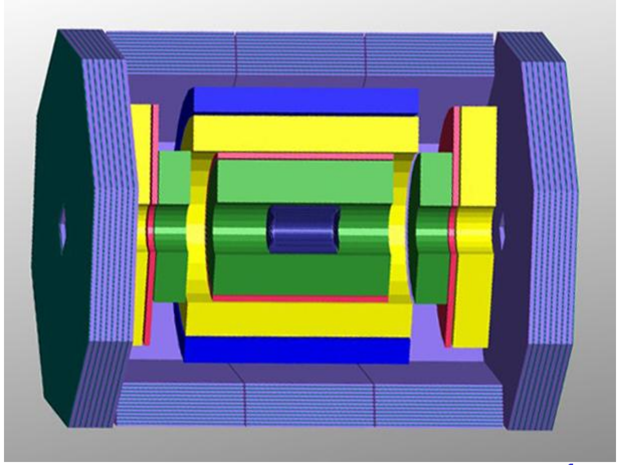
DY studies with SPD.
Toroid and/or Solenoid

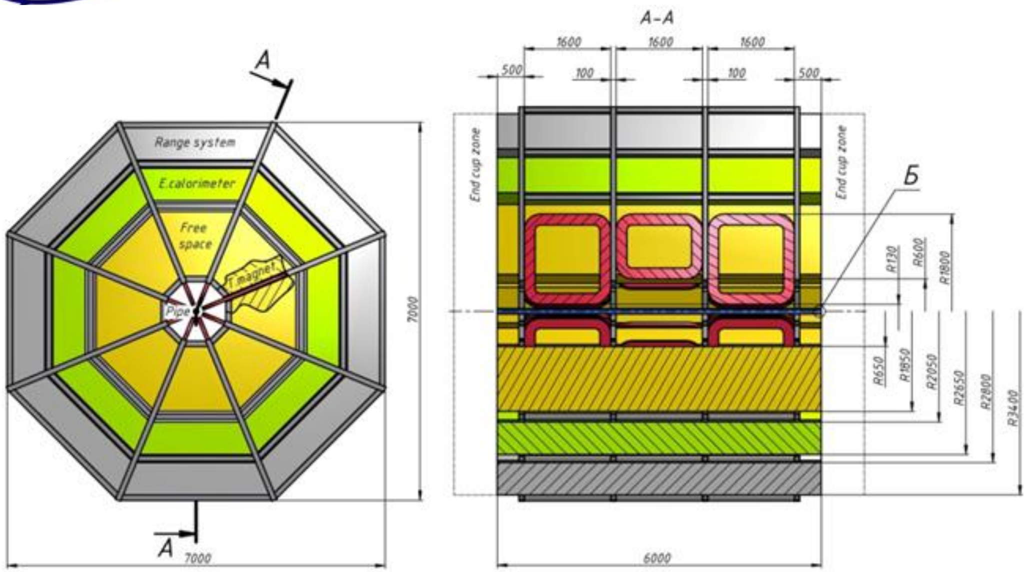
SPD DY team





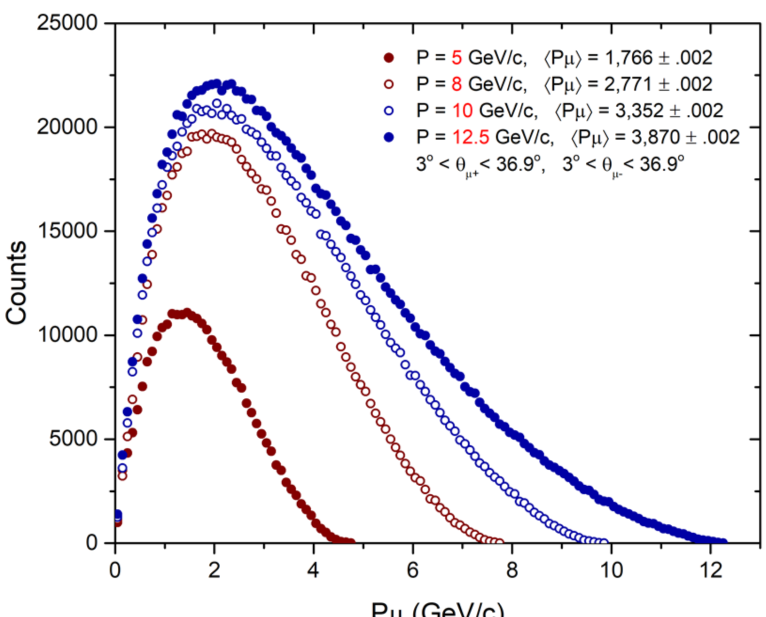


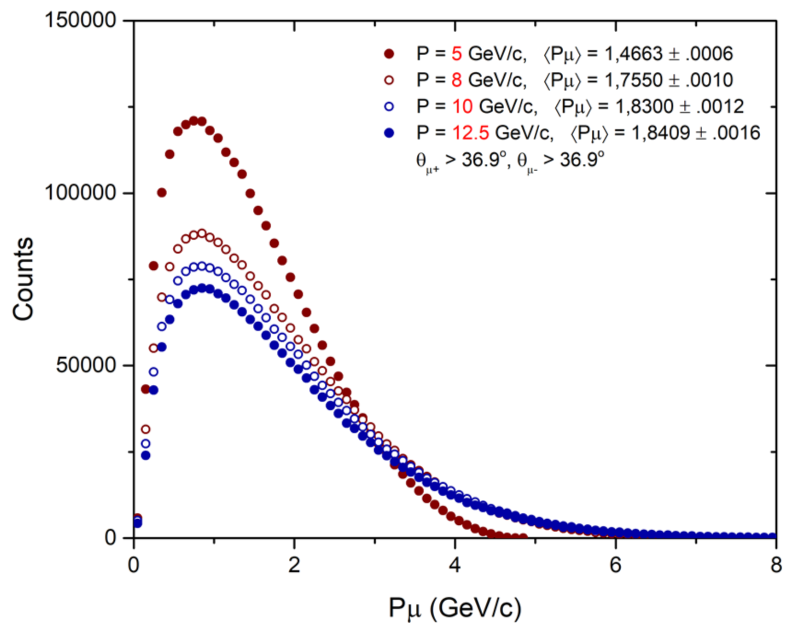
Toroid and/or Solenoid



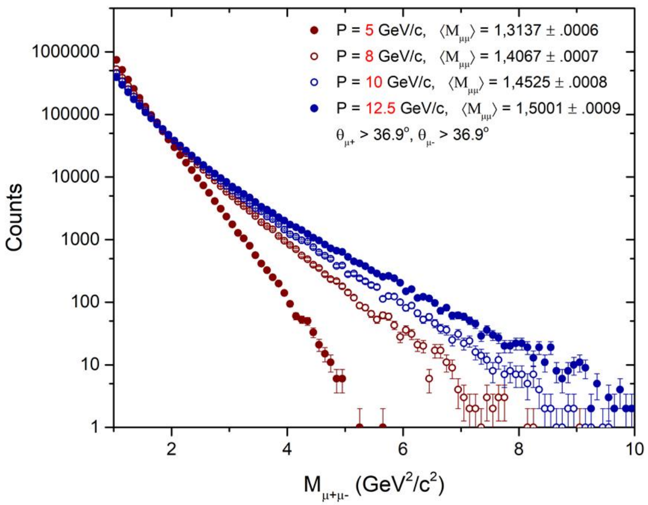

```
      PARP(2)=1.5d0      ! low limit c.m. energy
c---
      ckin(1)=1.0d0      ! ckin(1-2) range for m=sqrt(s)
      ckin(2)=-1.0d0     ! ckin(2), - inactive upper limit
c---
      MSEL=0                    ! turn OFF global process selection
      MSUB(1)=1                         ! turn ON q+qb -> 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
```

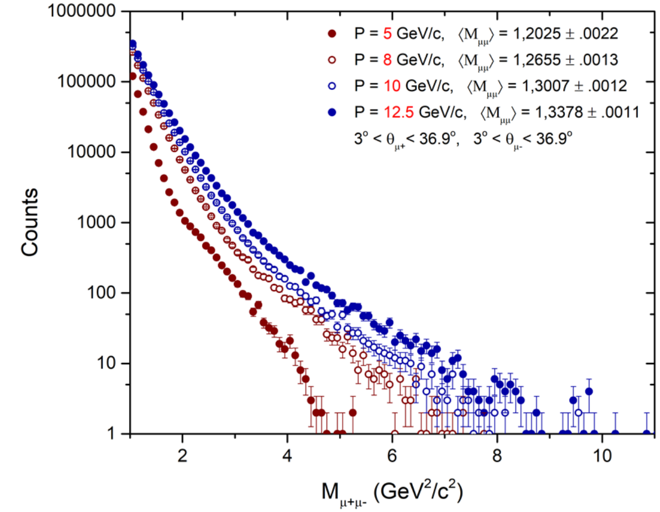
100 K events for both mag. system

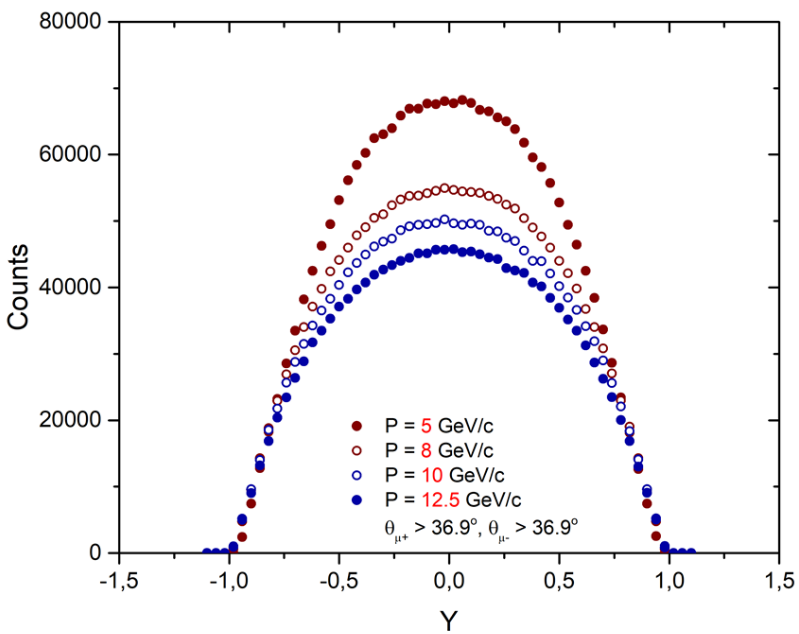


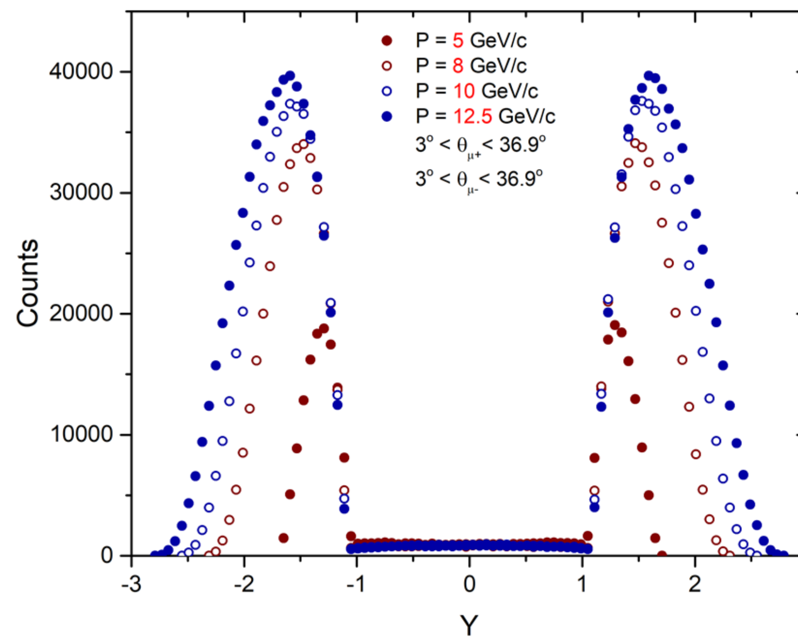


Toroid and/or Solenoid





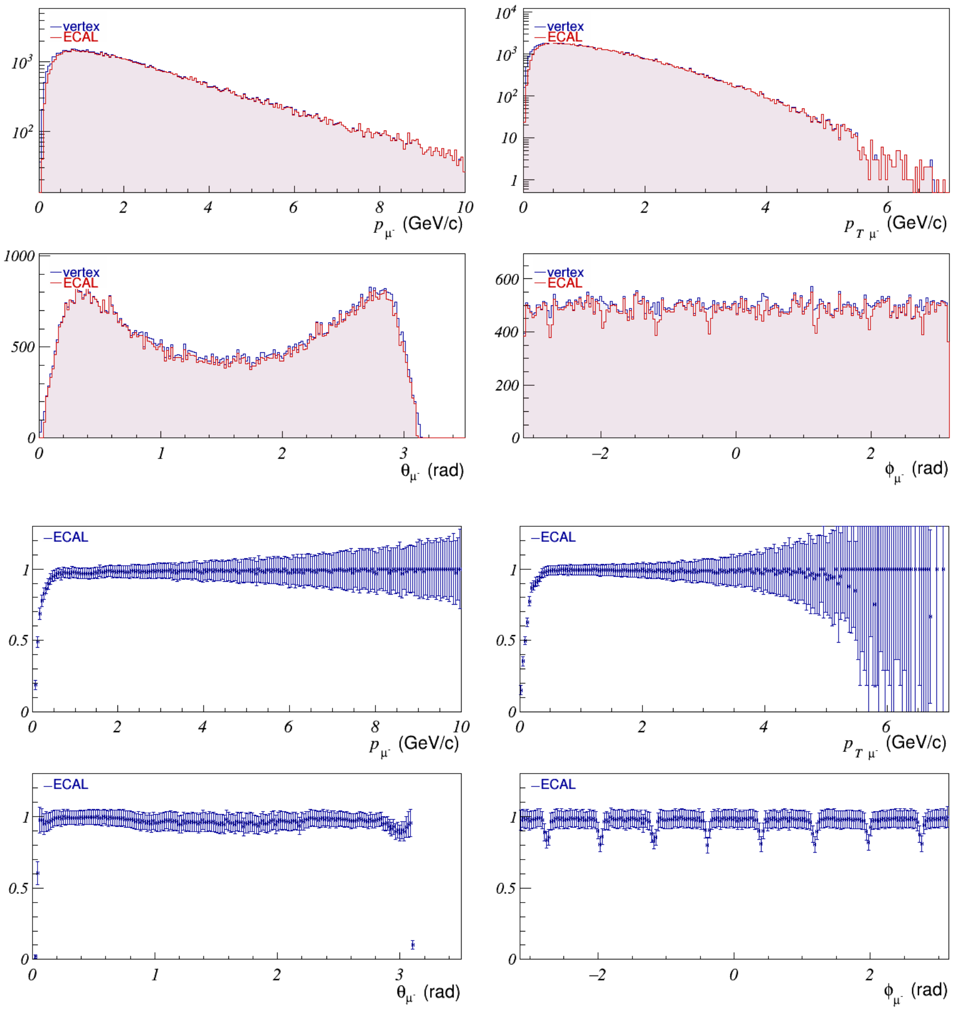




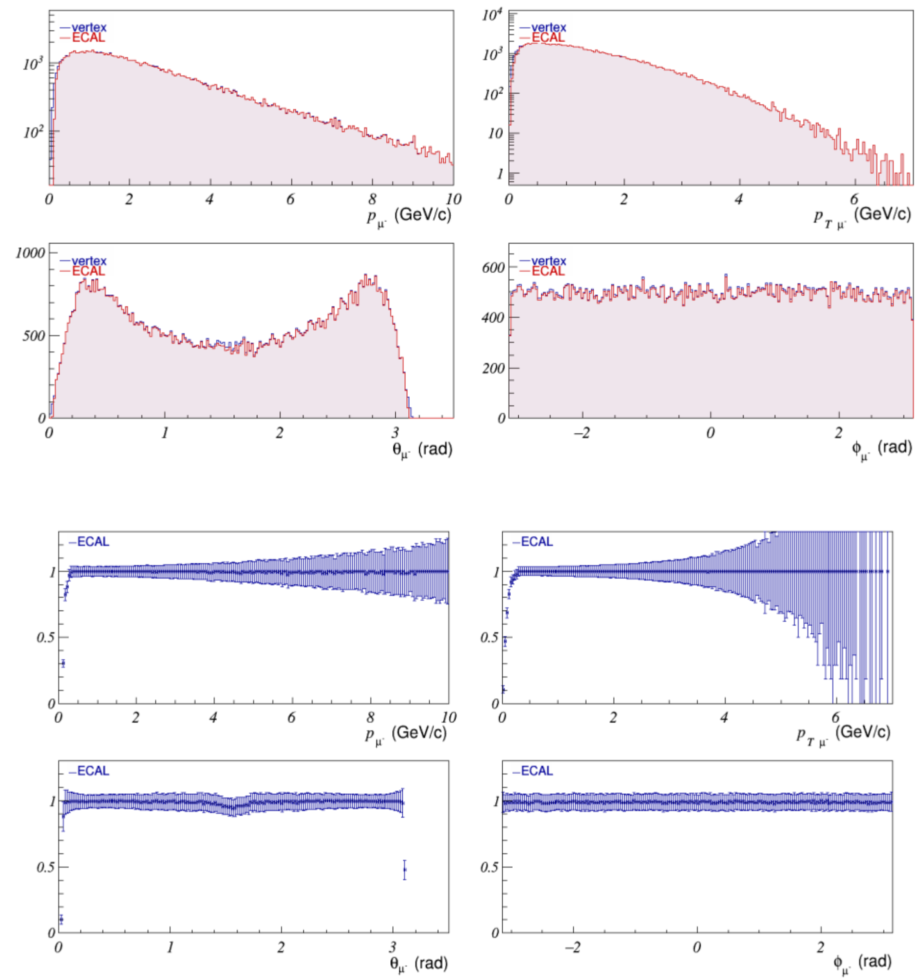
Toroid and/or Solenoid

μ^-

Toroid: DY in ECAL



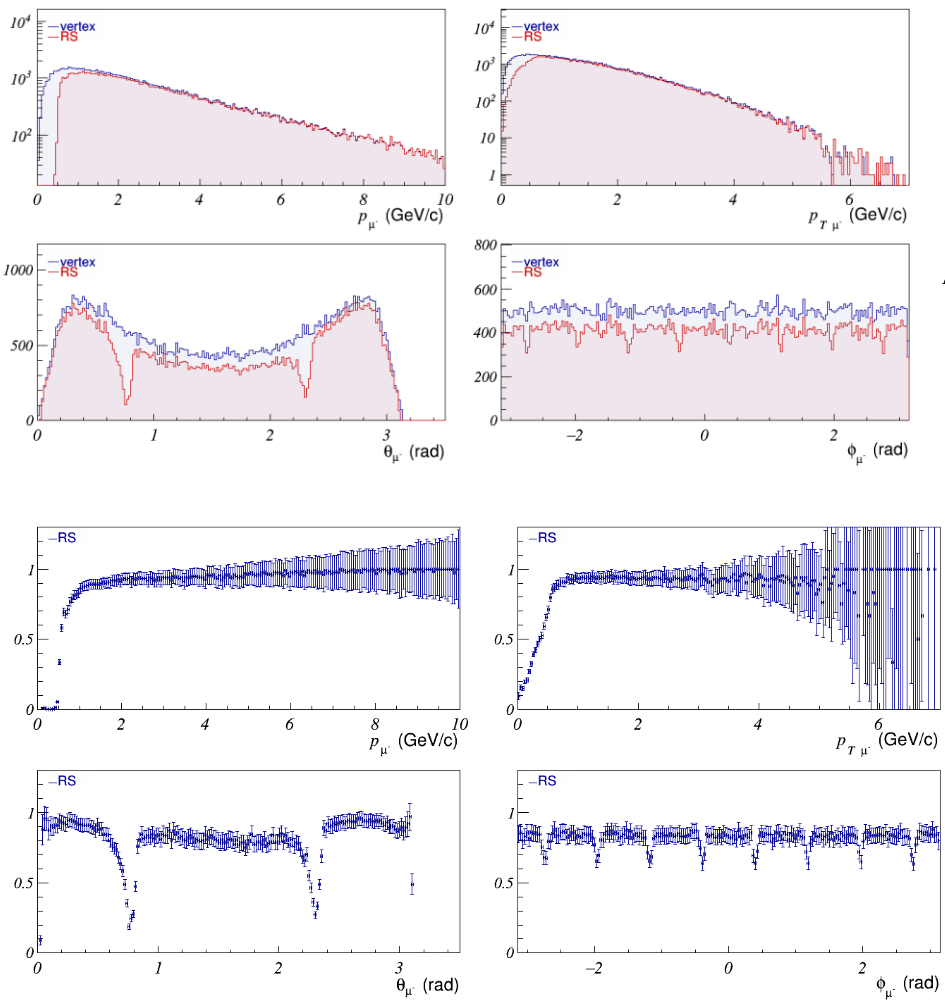
Solenoid : DY in ECAL



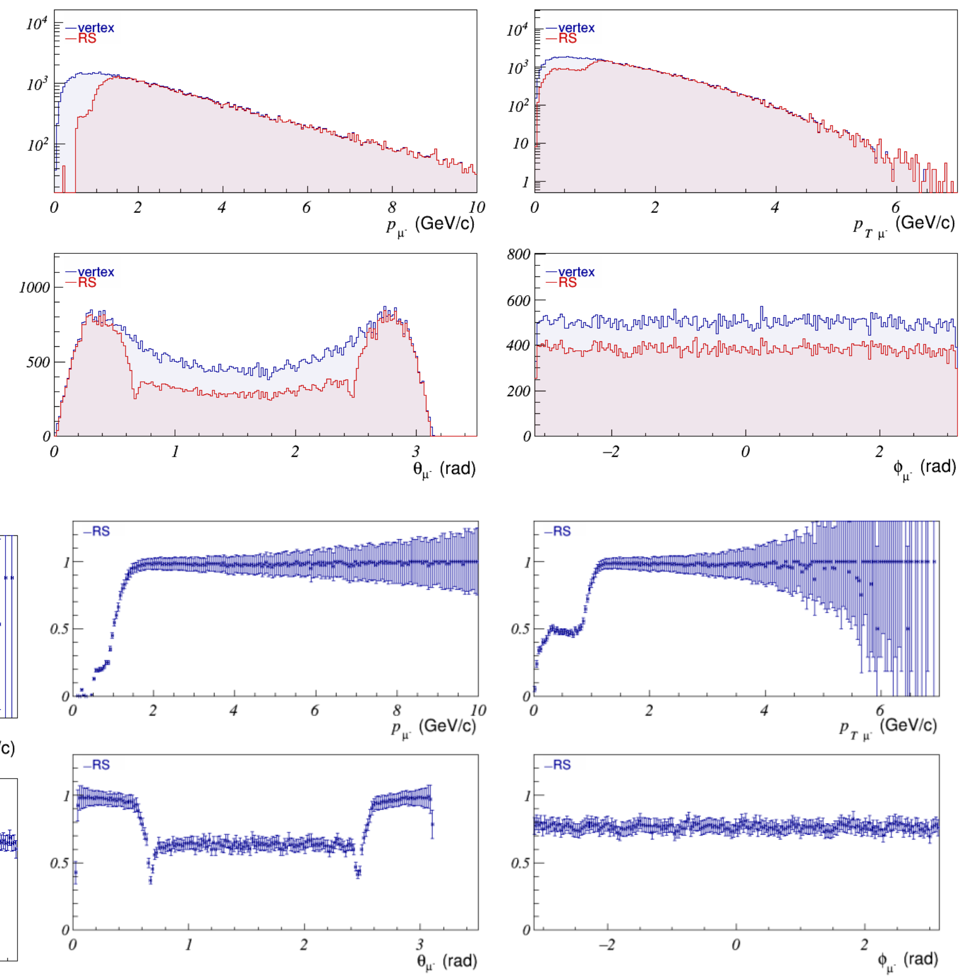
Toroid and/or Solenoid

μ^-

Toroid: DY in RS



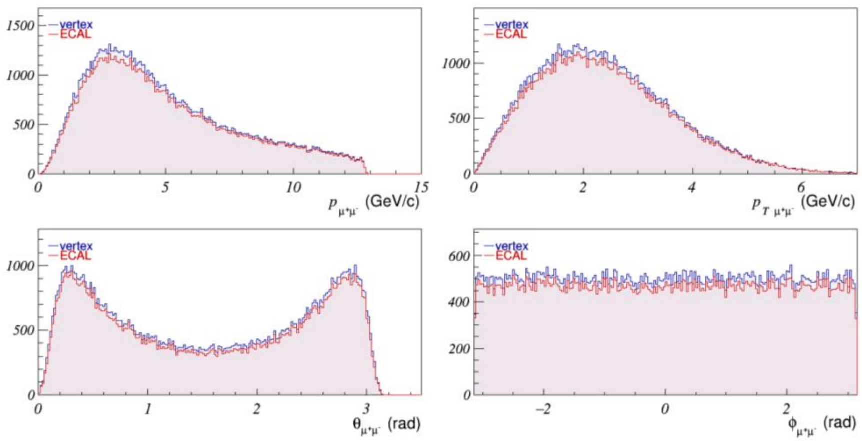
Solenoid : DY in RS



Toroid and/or Solenoid

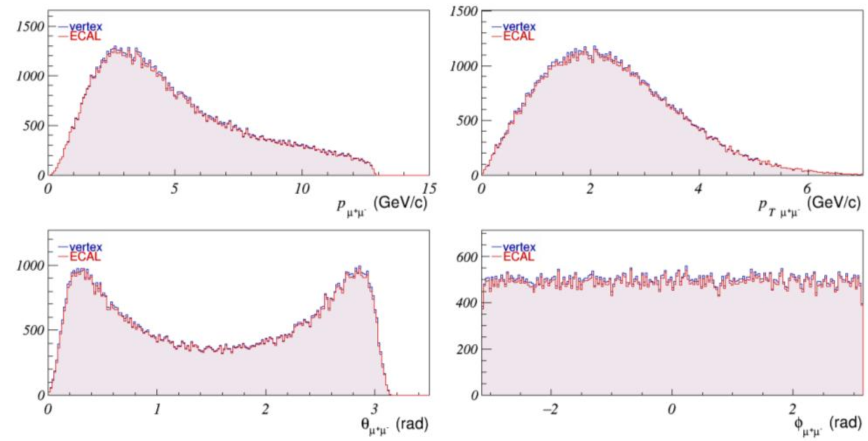
Toroid: DY in ECAL

$\mu^-\mu^+$



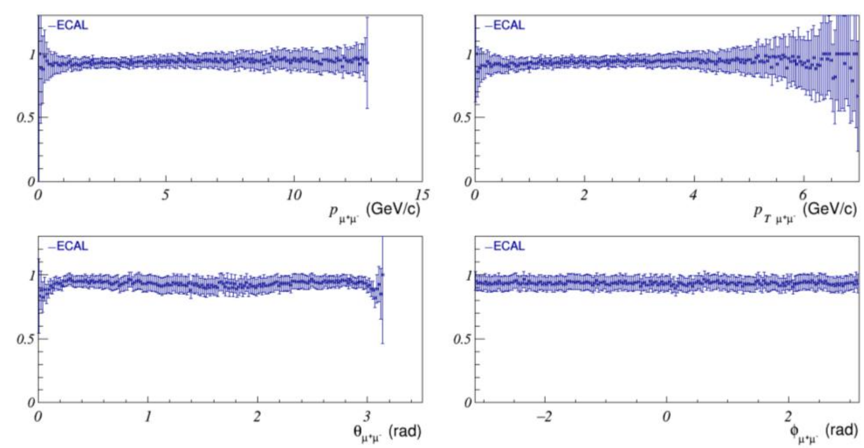
Solenoid : DY in ECAL

$\mu^-\mu^+$



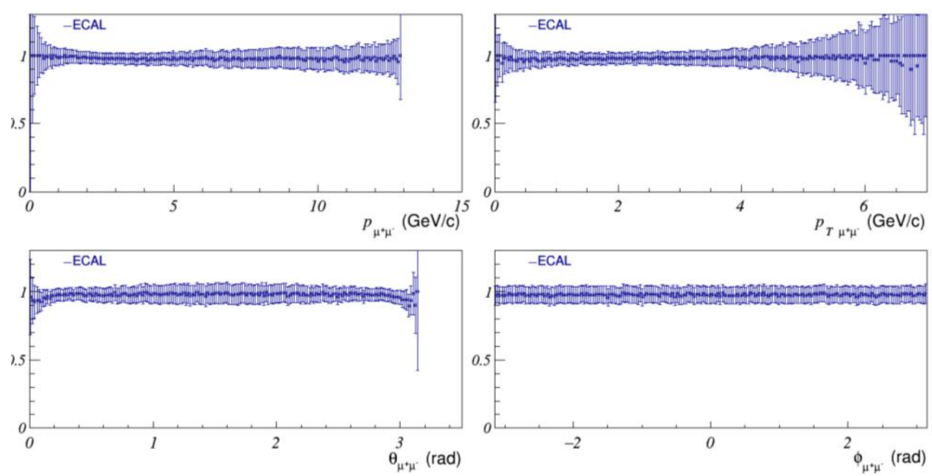
Toroid: DY in ECAL

$\mu^-\mu^+$



Solenoid : DY in ECAL

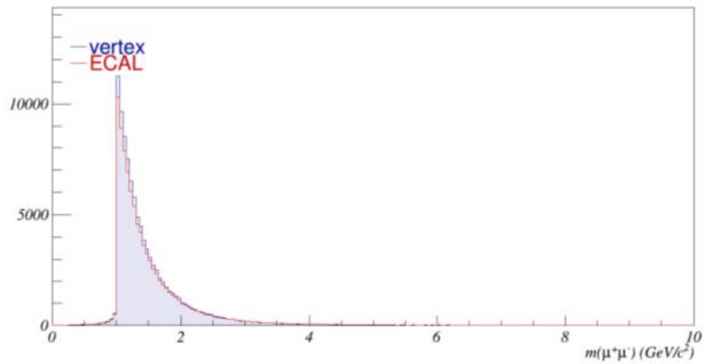
$\mu^-\mu^+$

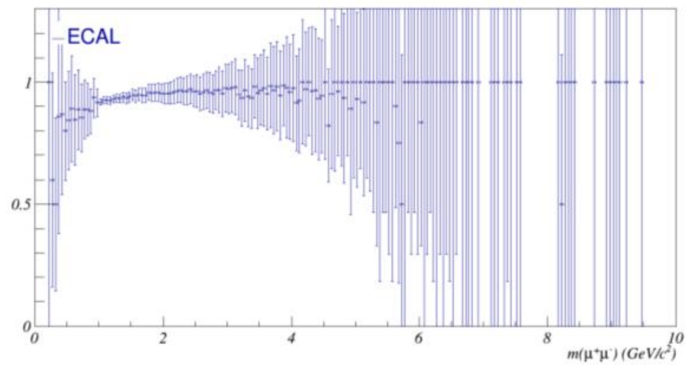


Toroid and/or Solenoid

Toroid: DY in ECAL

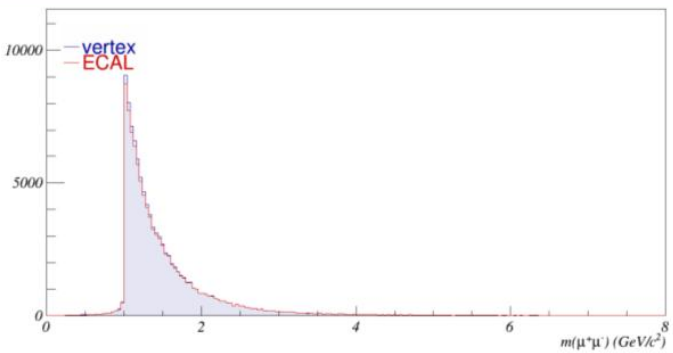
$\mu^-\mu^+$

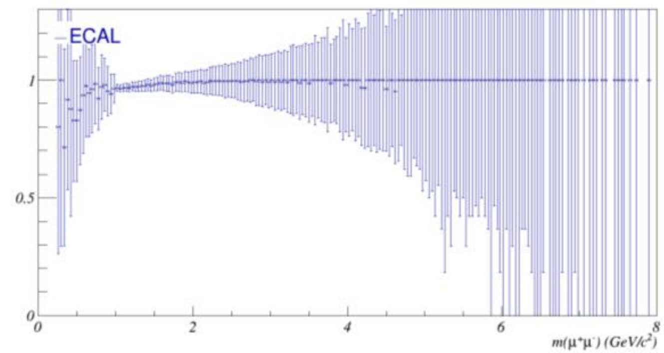




Solenoid : DY in ECAL

$\mu^-\mu^+$

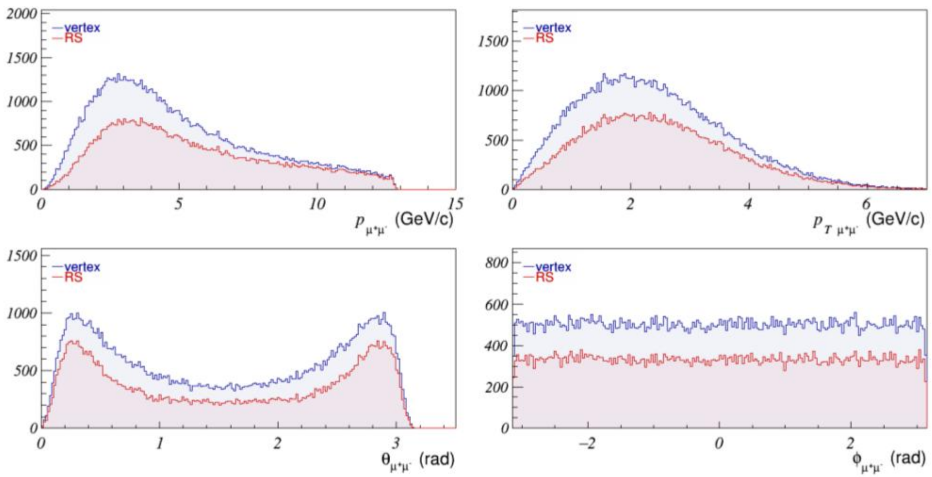




Toroid and/or Solenoid

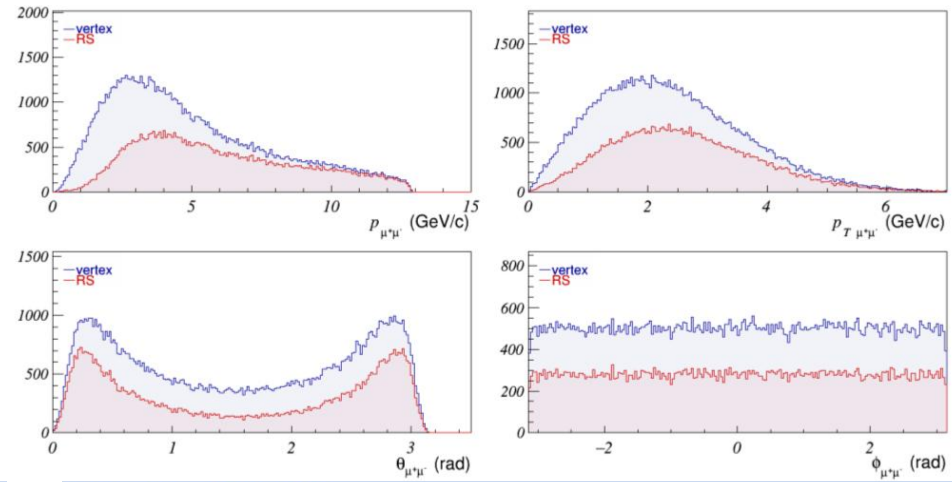
Toroid: DY in RS

$\mu^-\mu^+$



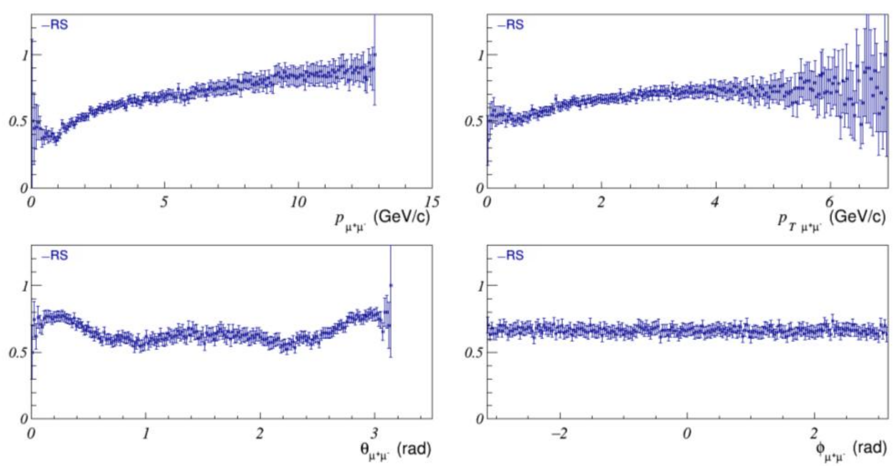
Solenoid : DY in RS

$\mu^-\mu^+$



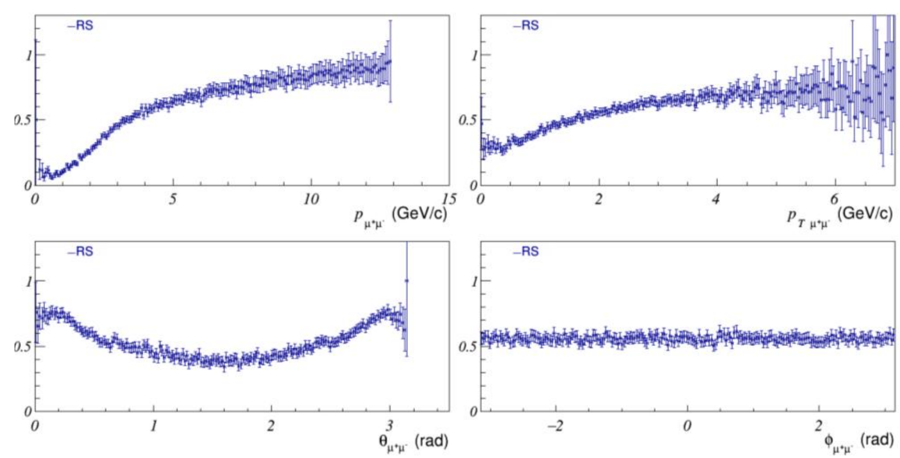
Toroid: DY in RS

$\mu^-\mu^+$



Solenoid : DY in RS

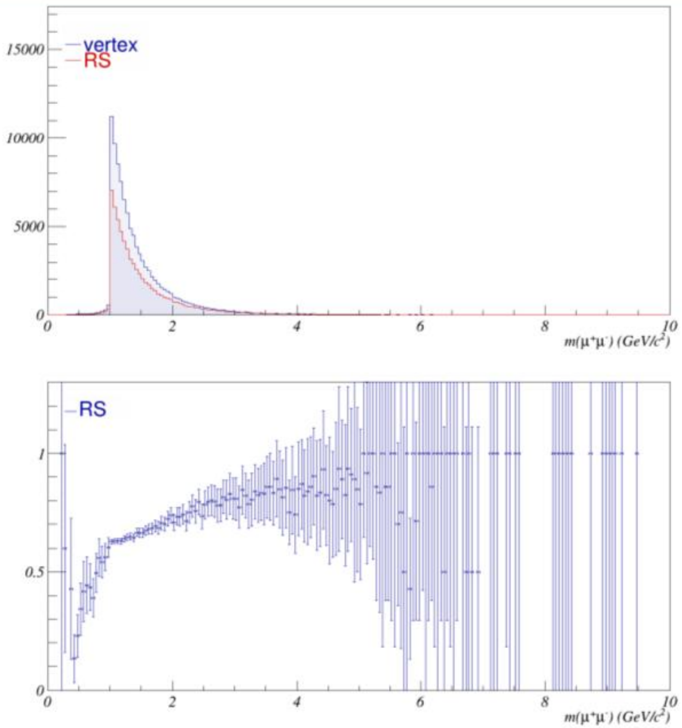
$\mu^-\mu^+$



Toroid and/or Solenoid

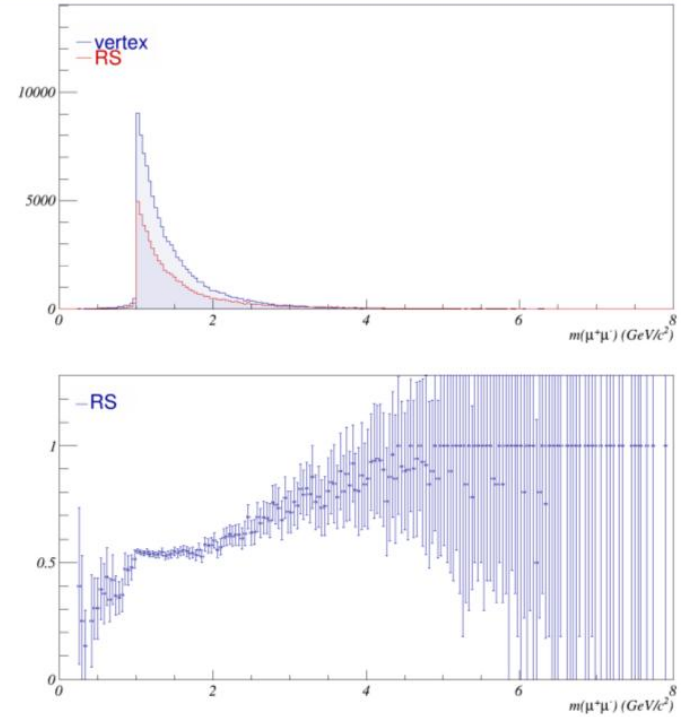
Toroid: DY in RS

$\mu^-\mu^+$



Solenoid : DY in RS

$\mu^-\mu^+$

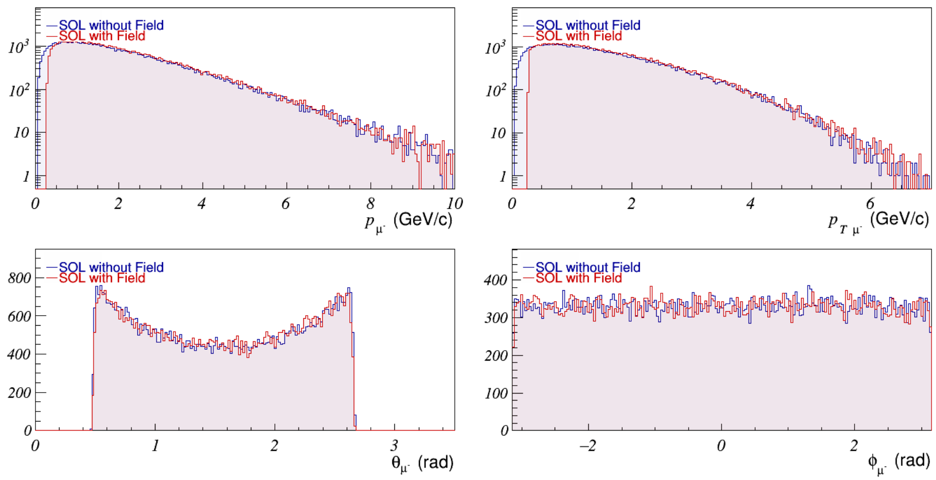


Detector	$\mu^{+/-}$ (%)		$\mu^+\mu^-$ (%)	
	Solenoid	Toroid	Solenoid	Toroid
ECAL	0.98	0.96	0.97	0.94
RS	0.76	0.82	0.55	0.66

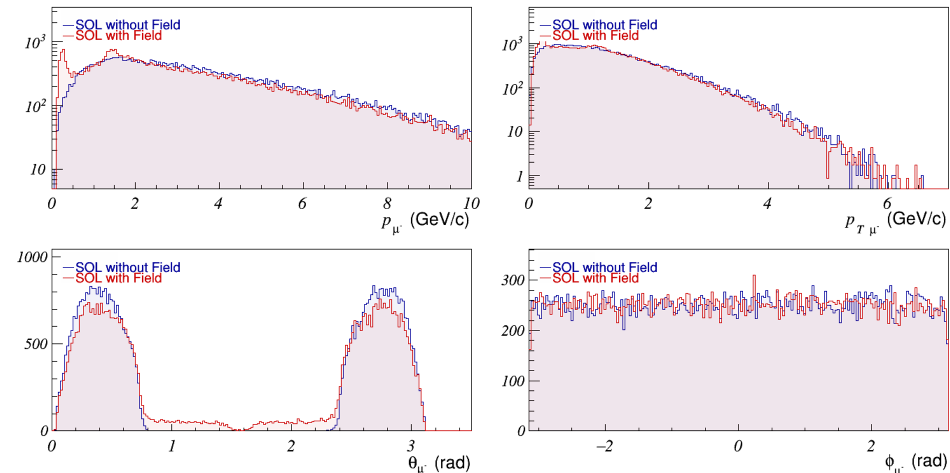
Toroid and/or Solenoid

Solenoid: ECAL

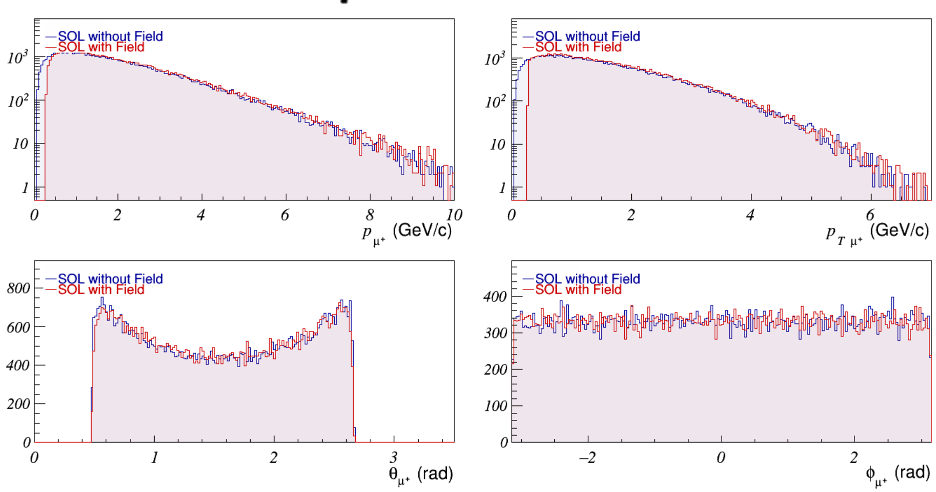
Barrel μ^-



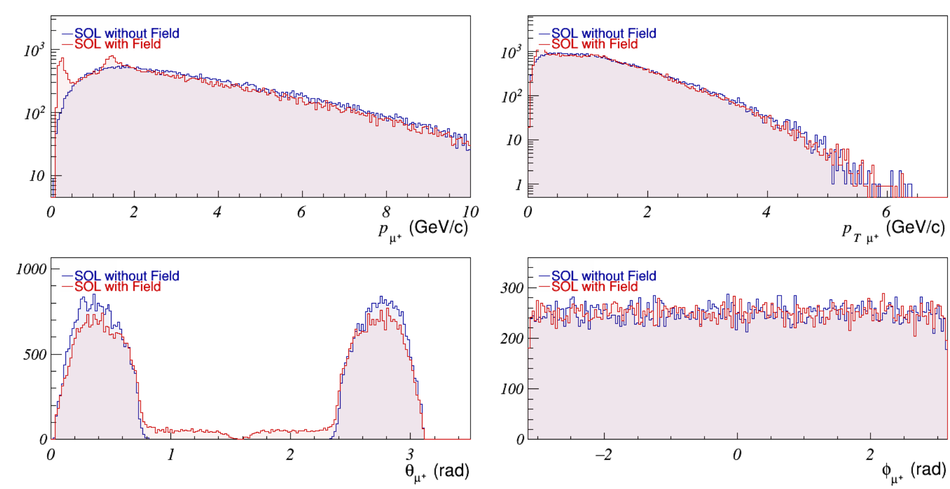
μ^- Endcaps



μ^+



μ^+

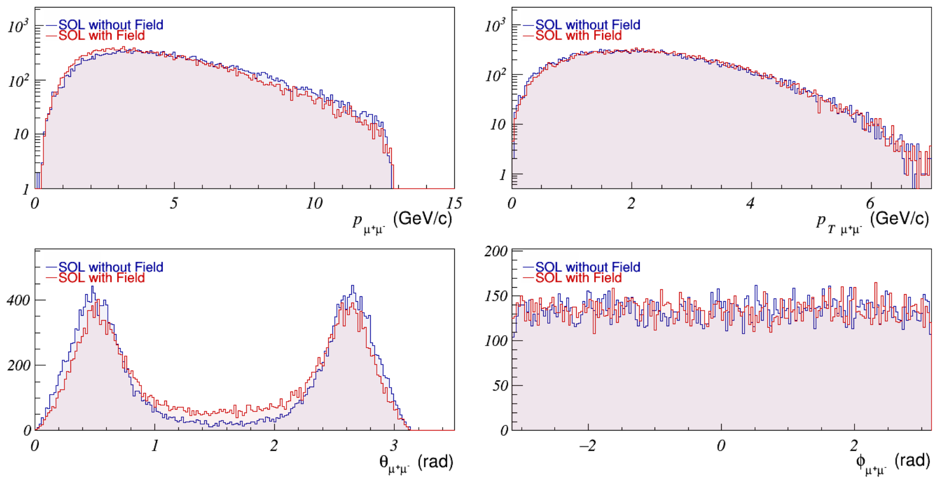


Toroid and/or Solenoid

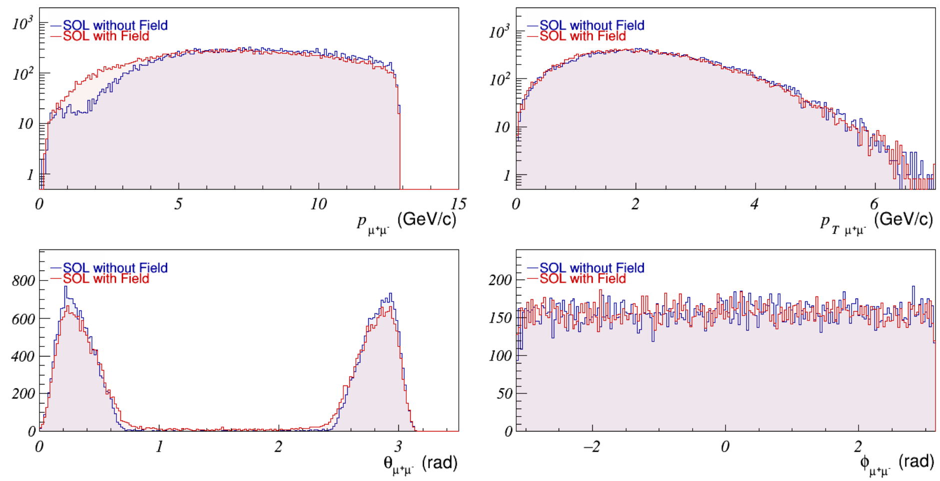
Solenoid: ECAL

Barrel Endcaps

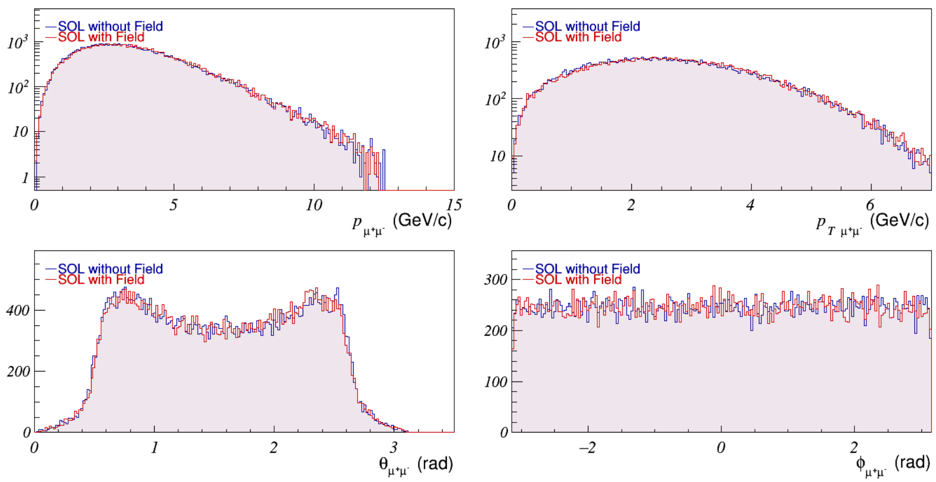
μ+μ−



Endcaps Endcaps



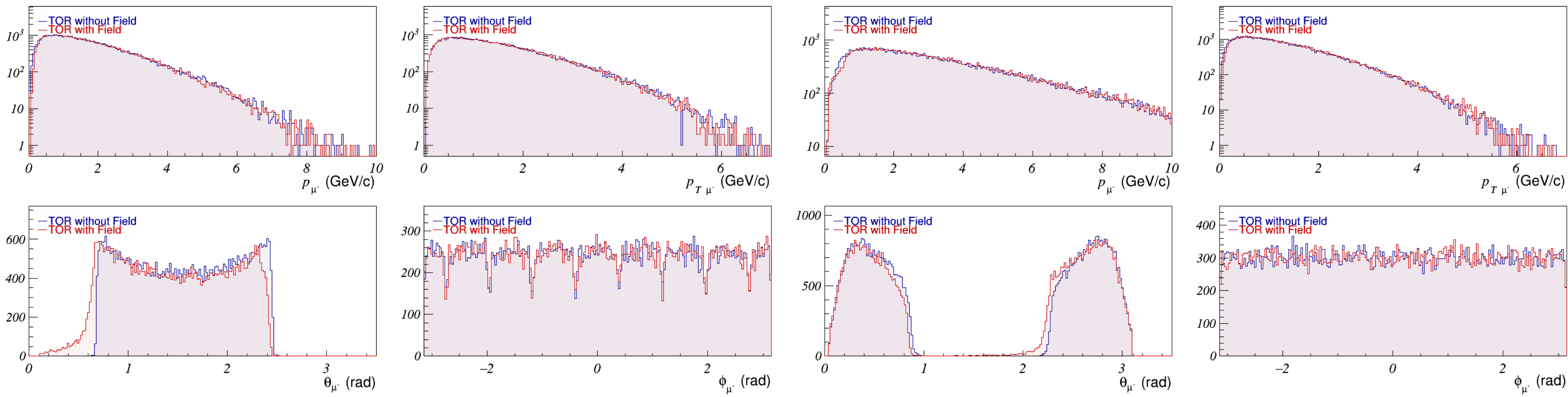
Barrel Barrel



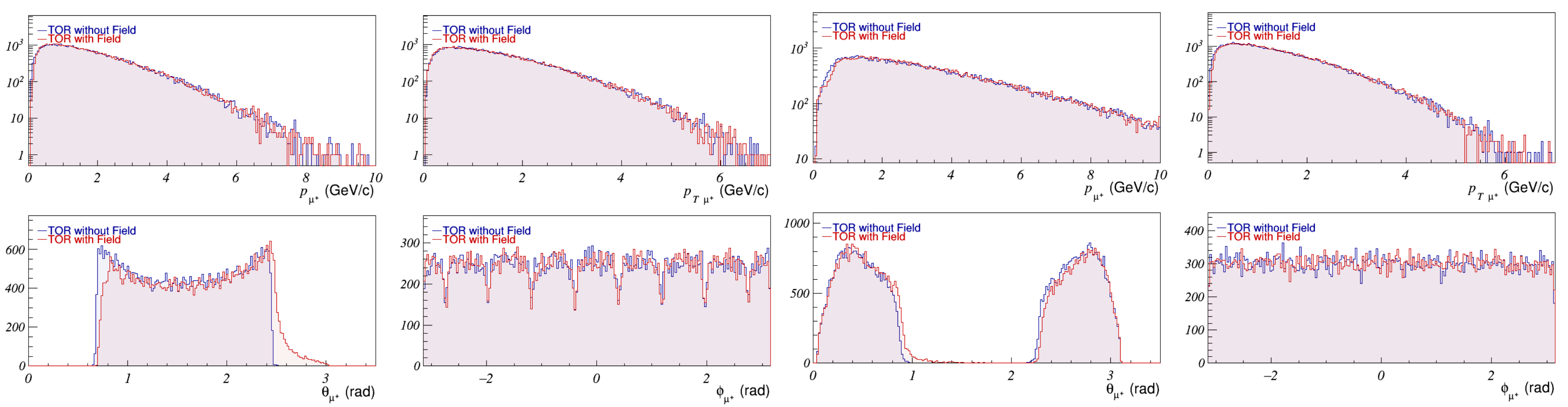
Toroid and/or Solenoid

Toroid: ECAL

Barrel μ^- μ^- Endcaps



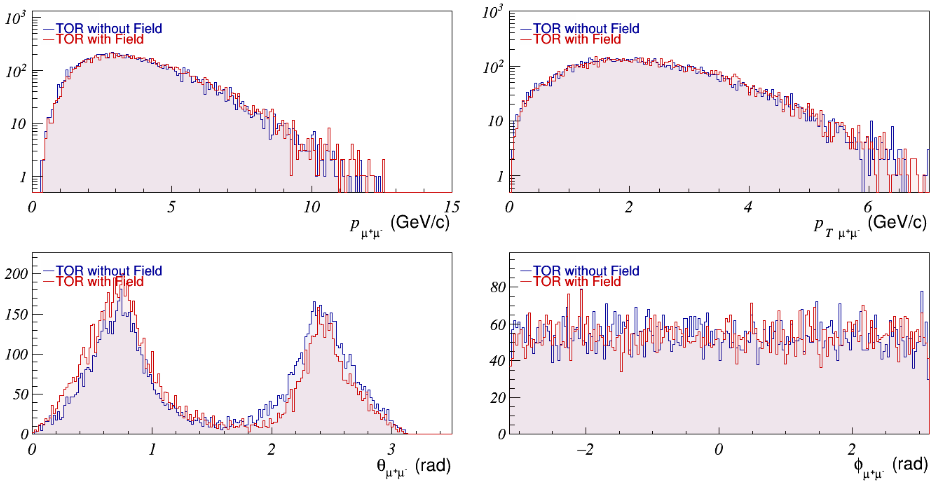
μ^+ μ^+



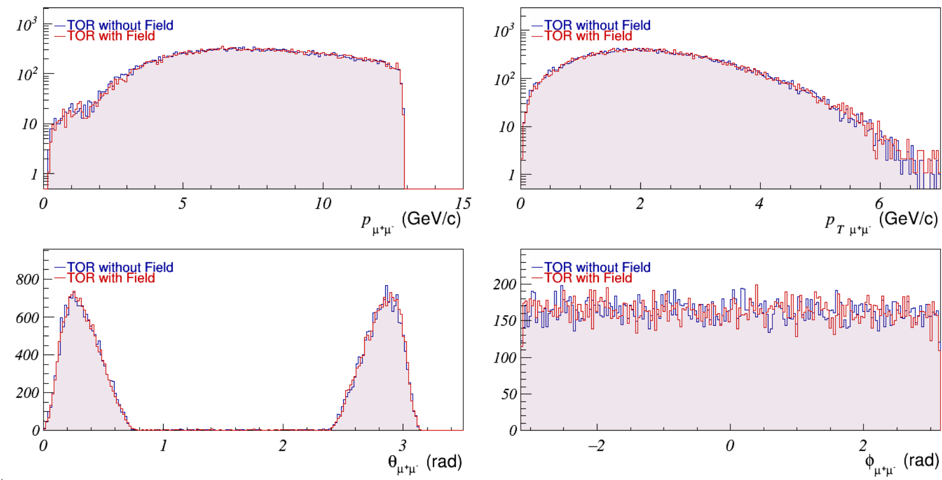
Toroid and/or Solenoid

Toroid: ECAL

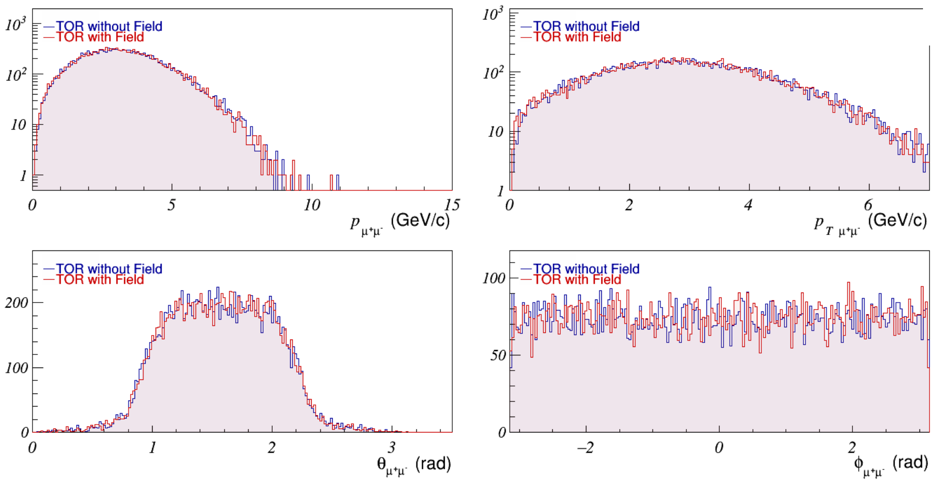
Barrel Endcaps μ+μ−



Endcaps Endcaps



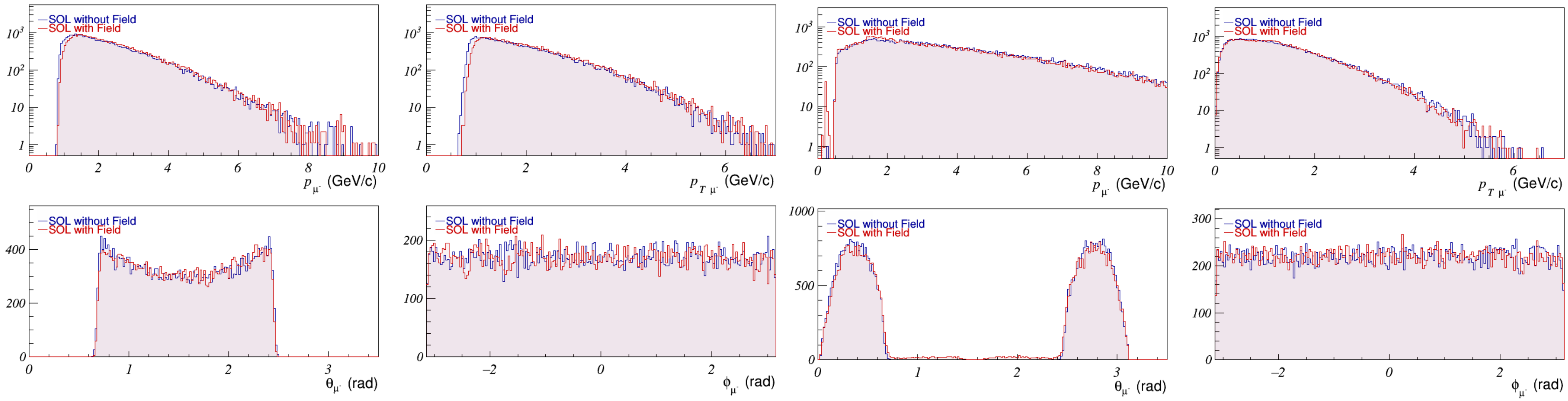
Barrel Barrel



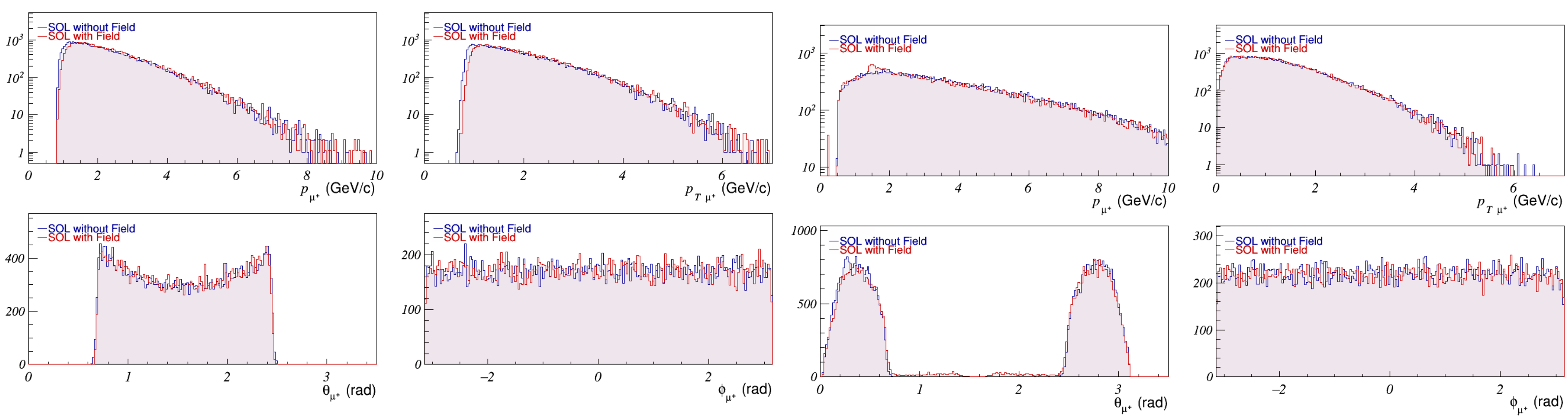
Toroid and/or Solenoid

Solenoid: RS

Barrel μ^- μ^- Endcaps



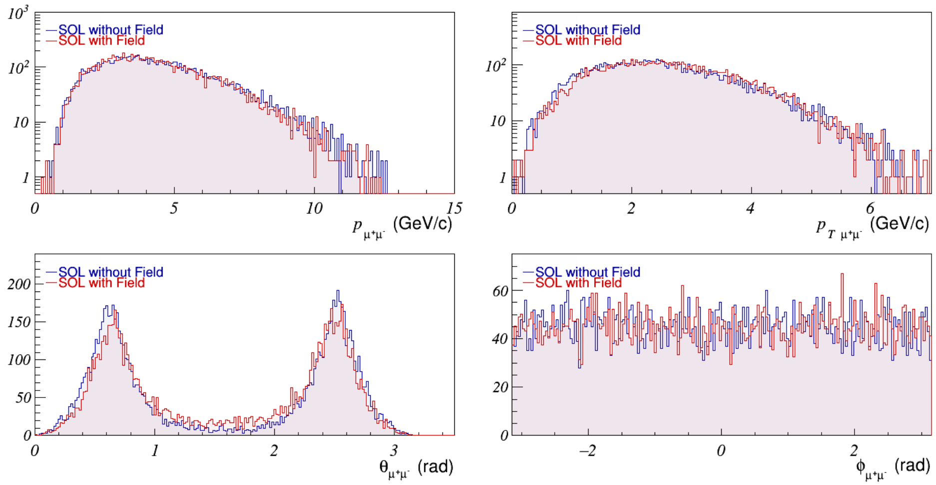
μ^+ μ^+



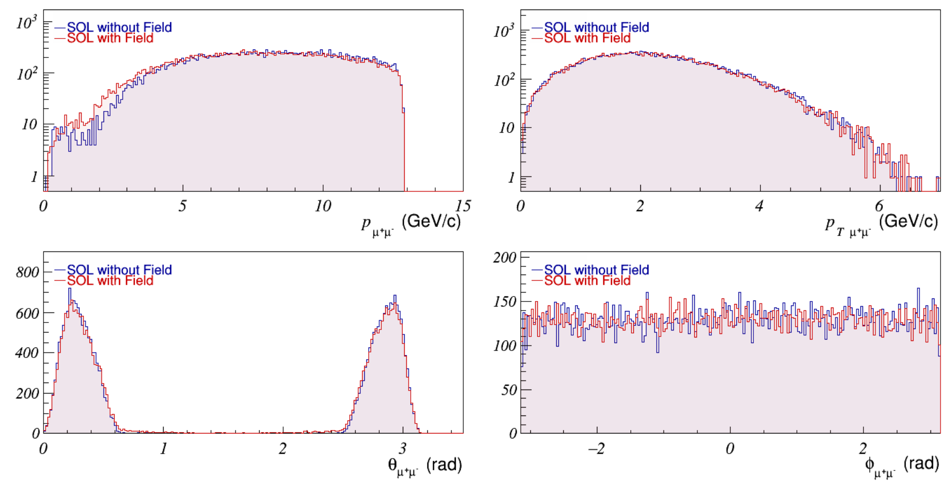
Toroid and/or Solenoid

Solenoid: RS

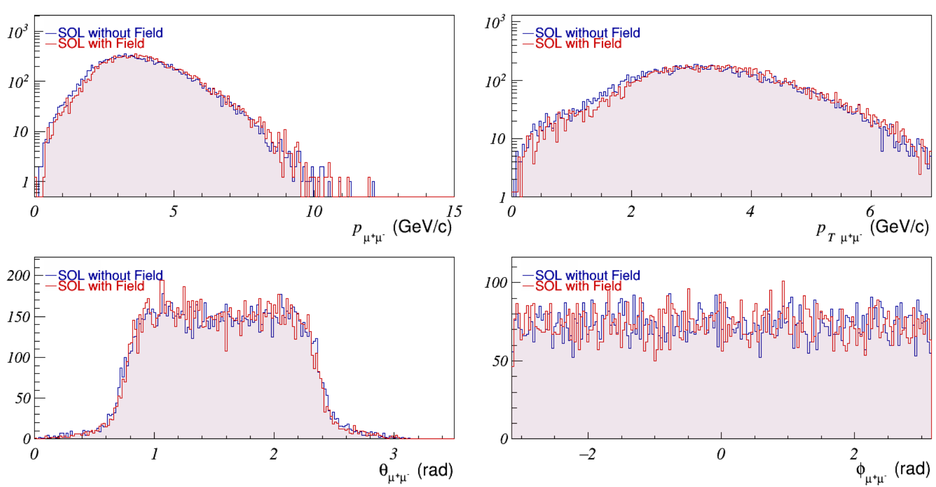
Barrel Endcaps μ+μ−



Endcaps Endcaps



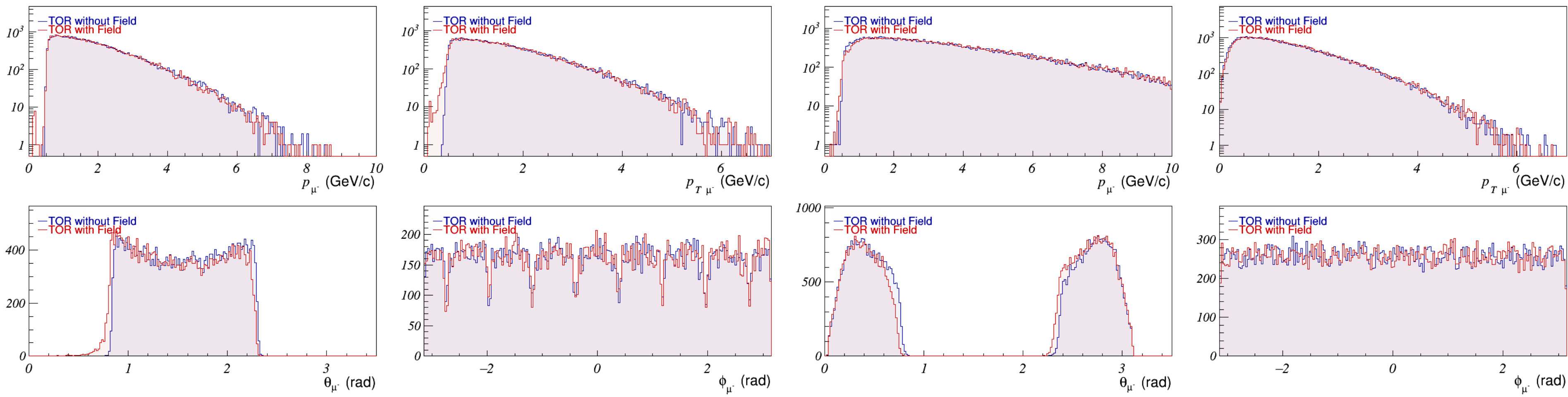
Barrel Barrel



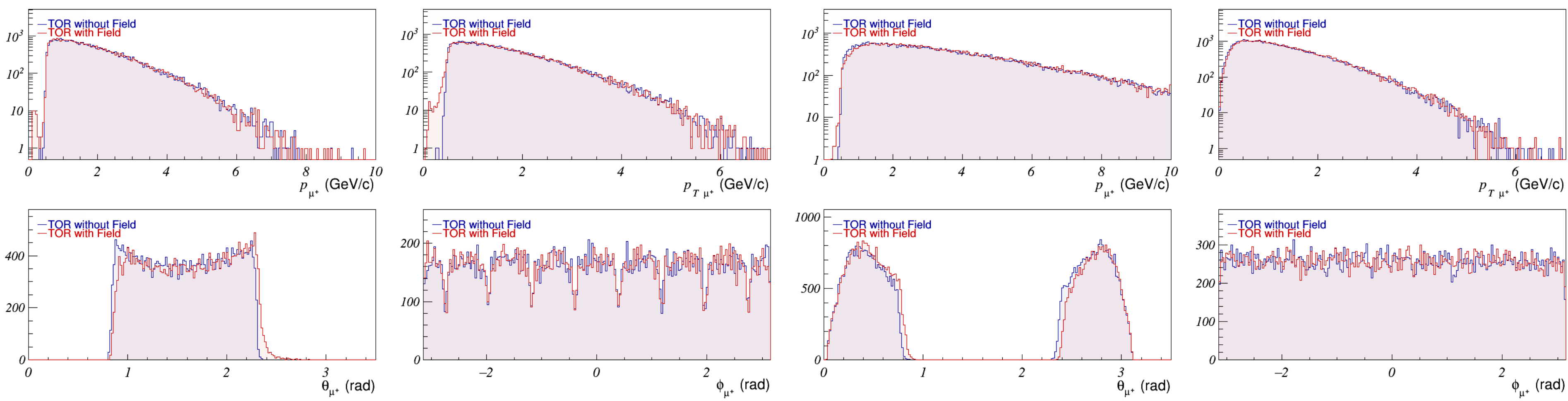
Toroid and/or Solenoid

Toroid: RS

Barrel μ^{-} μ^{-} **Endcaps**



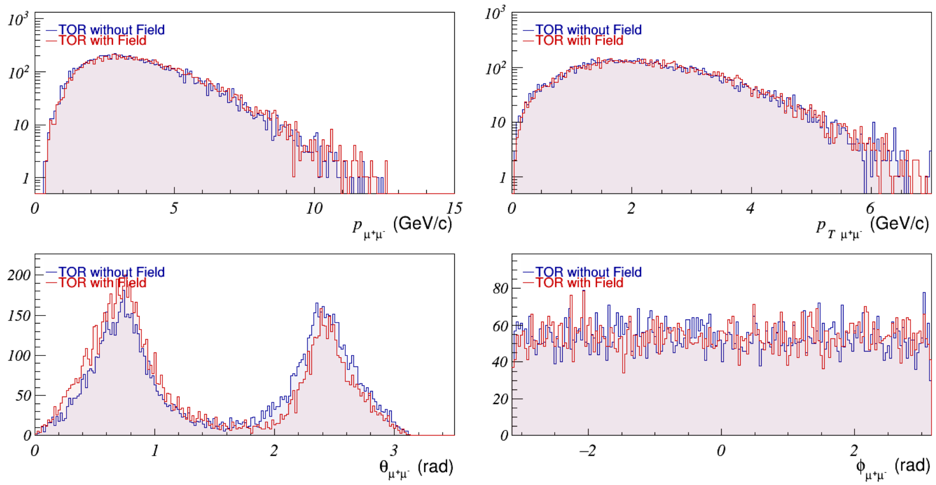
μ^{+} μ^{+}



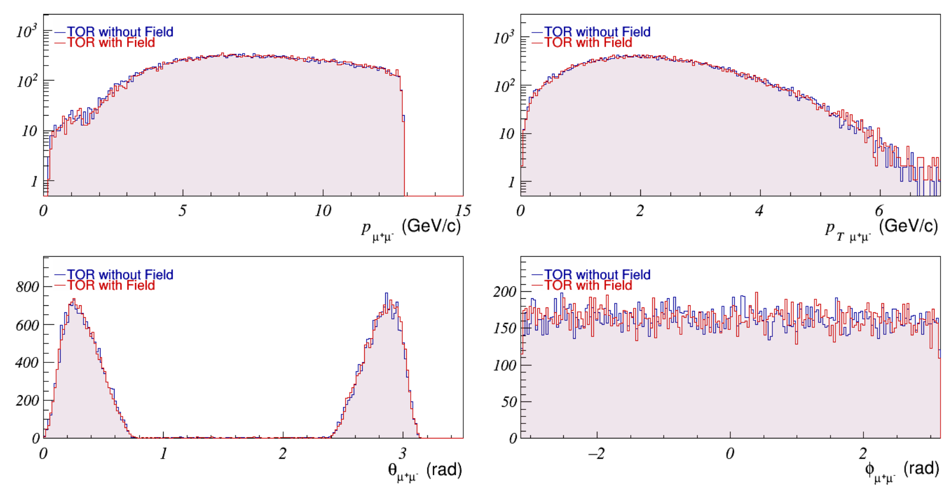
Toroid and/or Solenoid

Toroid: RS

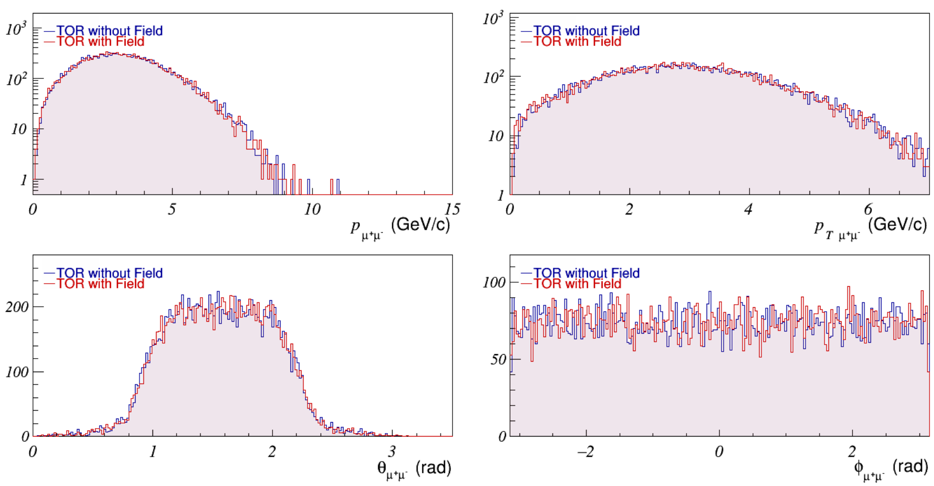
Barrel Endcaps $\mu+\mu-$



Endcaps Endcaps



Barrel Barrel



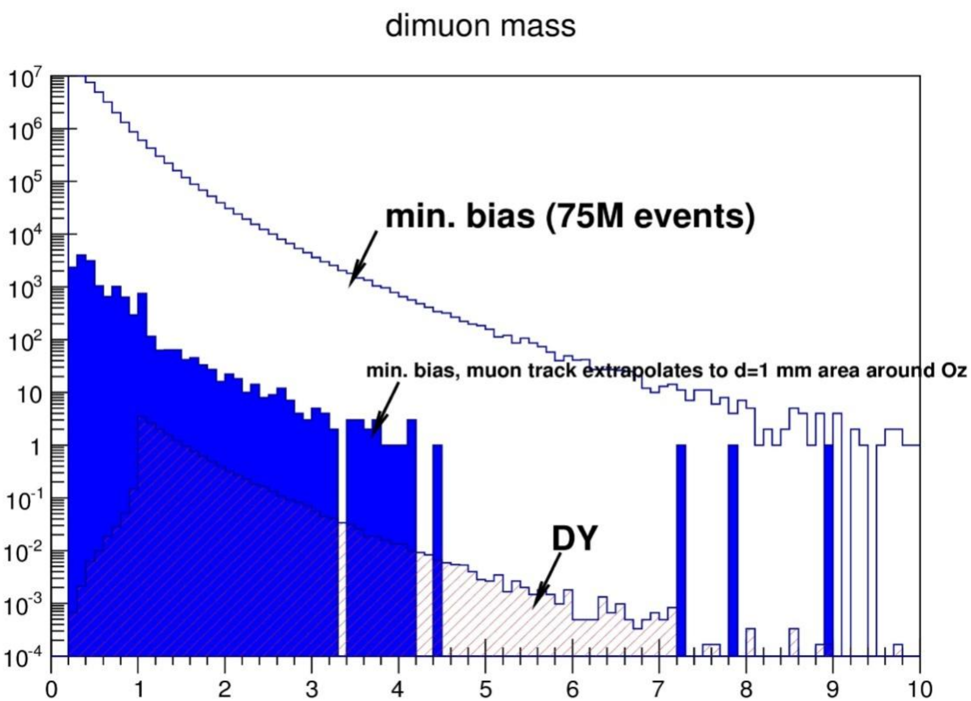
Toroid and/or Solenoid

DY background studies

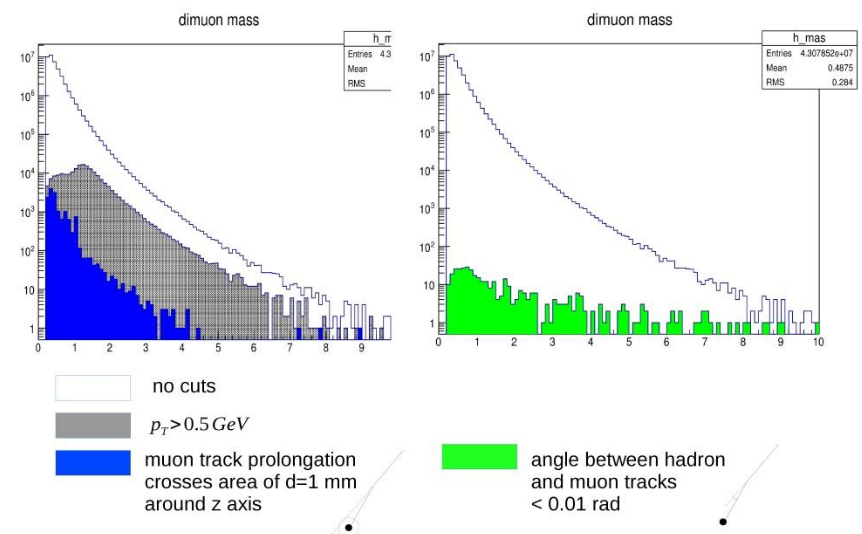
DY and min bias events were generated with PYTHIA 6

- 2 proton beams with E=12 GeV
- Only process $q\bar{q} \to \gamma^* \to \mu^+\mu^-$
- $m_{\mu\mu} > 1\,GeV$
- Decays of $\pi^{\pm}, K^{\pm}, K_L^0$ 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 $m_{\mu\mu} > 3\,GeV$ $\sigma_{tot} = 0.23\,nb$)

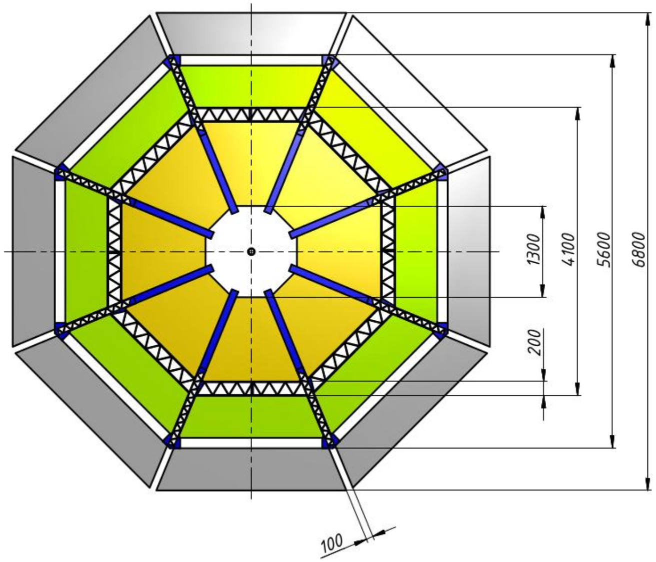


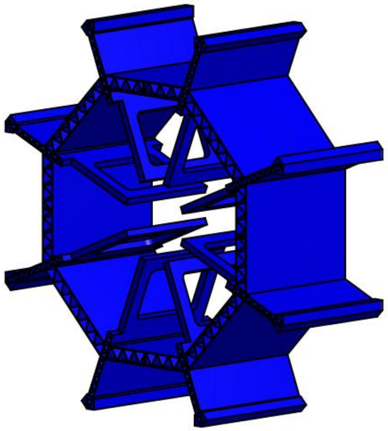
- PYTHIA 6
- MSEL=2
- 2 proton beams with E=12 GeV
- Decays of $\pi^{\pm}, K^{\pm}, K_L^0$ turned on
- $75 \cdot 10^6$ events
- $\sigma_{tot} = 39.4\,mb$

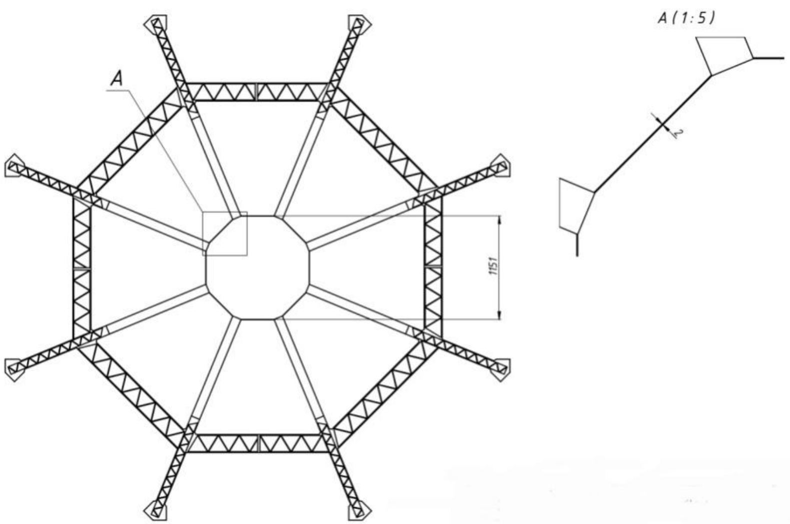


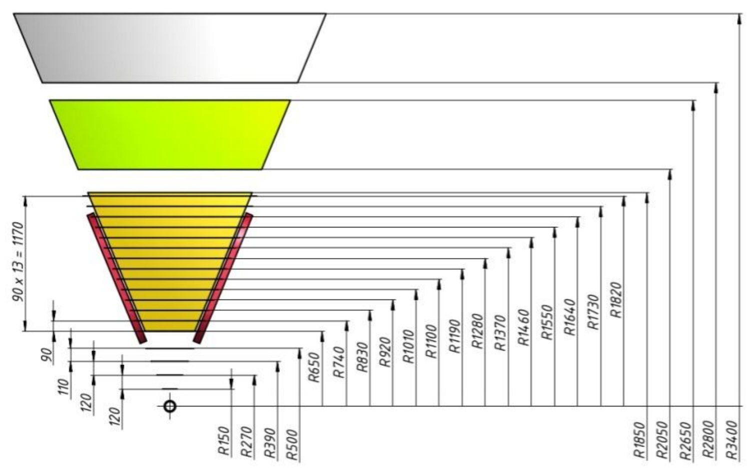
Tracking system has to be done with very high efficiency to reduce DY background.
OR use hadron absorber

Toroid and/or Solenoid







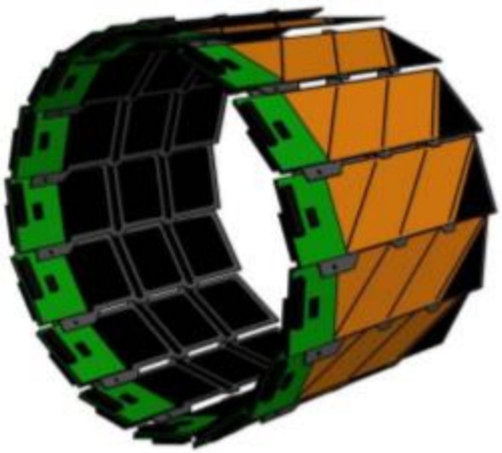


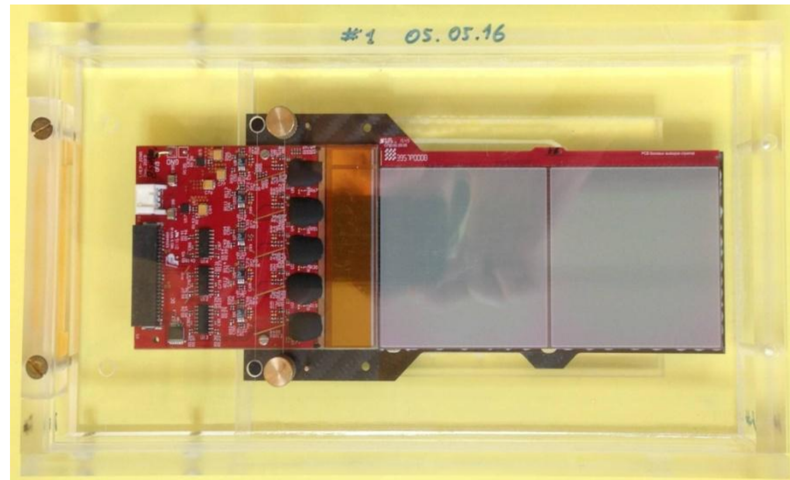
Радиус, мм	Длина, мм	Площадь, м2
150	1600	0,1491
270	1600	0,2684
390	1600	0,3877
500	1600	0,4971
650	6000	3,2309
740	6000	3,6782
830	6000	4,1256
920	6000	4,5729
1010	6000	5,0203
1100	6000	5,4676
1190	6000	5,9150
1280	6000	6,3623
1370	6000	6,8097
1460	6000	7,2570
1550	6000	7,7044
1640	6000	8,1517
1730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

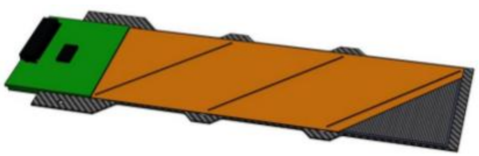
Toroid and/or Solenoid

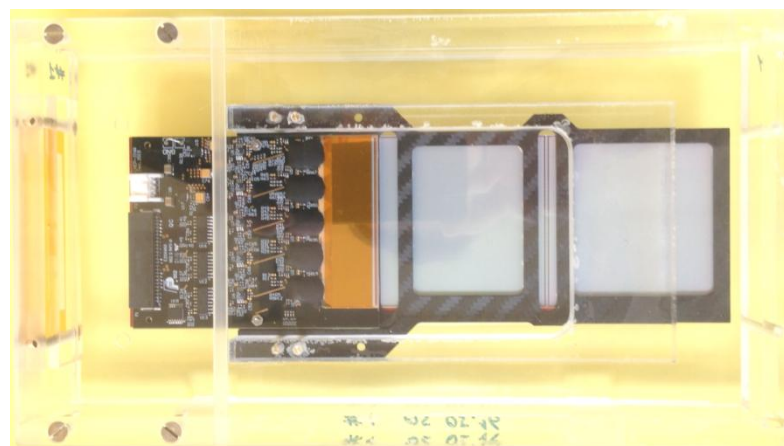
Possible view of Silicon detector

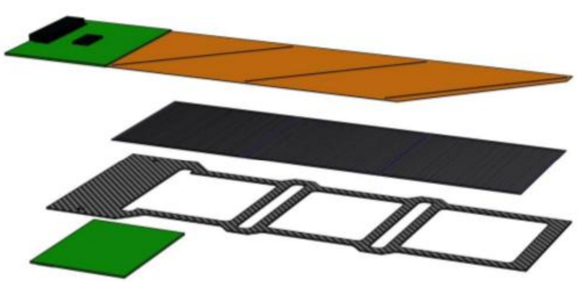
Dimensions of silicon detectors are 63 × 63 mm2, the sensitive area of detectors is 61 × 61 mm2, and the thickness of detectors is 300 μm.
The pitch of p+ strips is 95 μm and the pitch n+ is 103 μm.











Toroid and/or Solenoid

The central coordinate plane. NA62 straw system

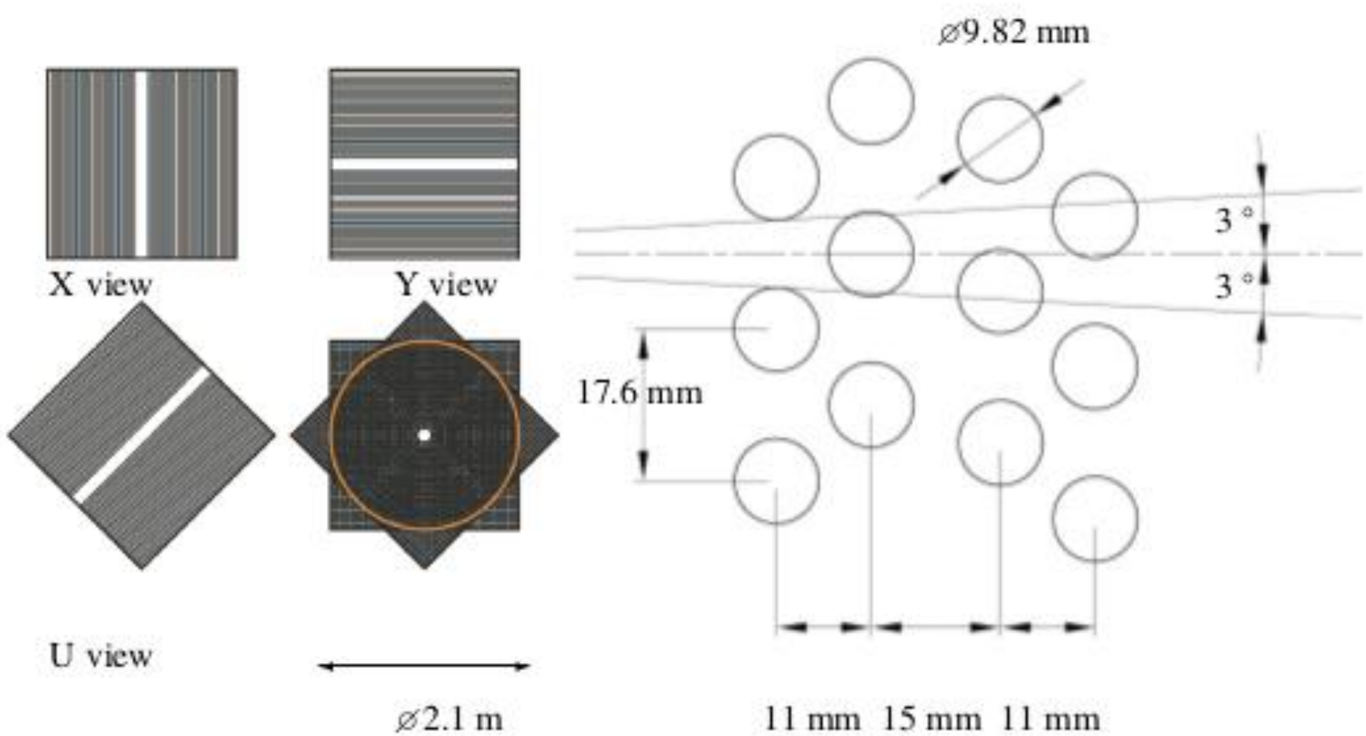
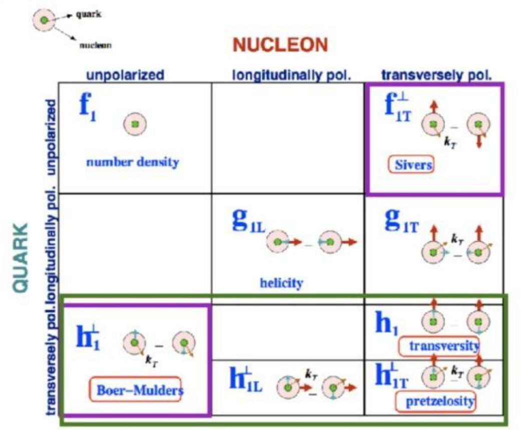


Figure 22. Left: one straw chamber is composed of four views (X, Y, U, V) and each view measures one coordinate. Near the middle of each view a few straws are left out forming a free passage for the beam. Right: the straw geometry is based on two double layers per view with sufficient overlap to guarantee 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.

CONCLUSIONS

Still no azimuthal asymmetries measurements in DY prosesses with collider experimental set-ups.

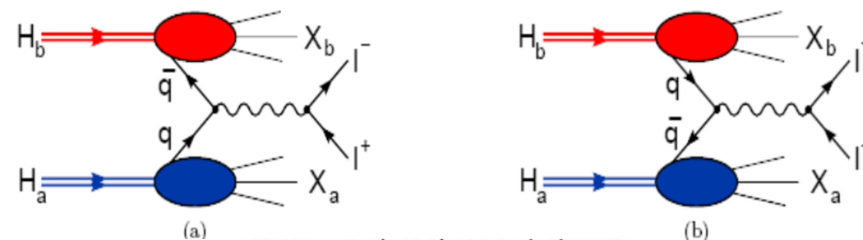
Drell-Yan studies with SPD.

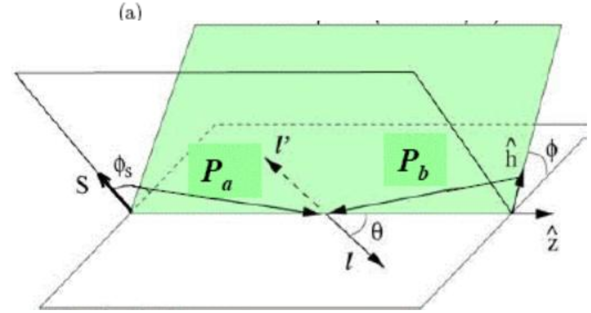


3 PDFs are needed to describe nucleon structure in collinear approximation

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

T-odd *chiral-odd*





$$\frac{d\sigma}{dx_a dx_b d^2q_T d\Omega} = \frac{\alpha^2}{4Q^2}\times$$
$$\Big\{\Big((1+\cos^2\theta)F_{UU}^1 + \sin^2\theta\cos 2\phi F_{UU}^{\cos 2\phi}\Big) + S_{aL}\sin^2\theta\sin 2\phi F_{LU}^{\sin 2\phi} + S_{bL}\sin^2\theta\sin 2\phi F_{UL}^{\sin 2\phi}$$
$$+\left|\vec{S}_{aT}\right|\Big[\sin(\phi-\phi_{S_a})\big(1+\cos^2\theta\big)F_{TU}^{\sin(\phi-\phi_{S_a})} + \sin^2\theta\Big(\sin(3\phi-\phi_{S_a})F_{TU}^{\sin(3\phi-\phi_{S_a})} + \sin(\phi+\phi_{S_a})F_{TU}^{\sin(\phi+\phi_{S_a})}\Big)\Big]$$
$$+\left|\vec{S}_{bT}\right|\Big[\sin(\phi-\phi_{S_b})\big(1+\cos^2\theta\big)F_{UT}^{\sin(\phi-\phi_{S_b})} + \sin^2\theta\Big(\sin(3\phi-\phi_{S_b})F_{UT}^{\sin(3\phi-\phi_{S_b})} + \sin(\phi+\phi_{S_b})F_{UT}^{\sin(\phi+\phi_{S_b})}\Big)\Big]$$
$$+S_{aL}S_{bL}\Big[\big(1+\cos^2\theta\big)F_{LL}^1 + \sin^2\theta\cos 2\phi F_{LL}^{\cos 2\phi}\Big] \qquad (2.1.2)$$
$$+S_{aL}\left|\vec{S}_{bT}\right|\Big[\cos(\phi-\phi_{S_b})\big(1+\cos^2\theta\big)F_{LT}^{\cos(\phi-\phi_{S_b})} + \sin^2\theta\Big(\cos(3\phi-\phi_{S_b})F_{LT}^{\cos(3\phi-\phi_{S_b})} + \cos(\phi+\phi_{S_b})F_{LT}^{\cos(\phi+\phi_{S_b})}\Big)\Big]$$
$$+\left|\vec{S}_{aT}\right|S_{bL}\Big[\cos(\phi-\phi_{S_a})\big(1+\cos^2\theta\big)F_{TL}^{\cos(\phi-\phi_{S_a})} + \sin^2\theta\Big(\cos(3\phi-\phi_{S_a})F_{TL}^{\cos(3\phi-\phi_{S_a})} + \cos(\phi+\phi_{S_a})F_{TL}^{\cos(\phi+\phi_{S_a})}\Big)\Big]$$
$$+\left|\vec{S}_{aT}\right|\left|\vec{S}_{bT}\right|\Big[\big(1+\cos^2\theta\big)\Big(\cos(2\phi-\phi_{S_a}-\phi_{S_b})F_{TT}^{\cos(2\phi-\phi_{S_a}-\phi_{S_b})} + \cos(\phi_{S_b}-\phi_{S_a})F_{TT}^{\cos(\phi_{S_b}-\phi_{S_a})}\Big)\Big]$$
$$+\left|\vec{S}_{aT}\right|\left|\vec{S}_{bT}\right|\Big[\sin^2\theta\Big(\cos(\phi_{S_a}+\phi_{S_b})F_{TT}^{\cos(\phi_{S_a}+\phi_{S_b})} + \cos(4\phi-\phi_{S_a}-\phi_{S_b})F_{TT}^{\cos(4\phi-\phi_{S_a}-\phi_{S_b})}\Big)\Big]$$
$$+\left|\vec{S}_{aT}\right|\left|\vec{S}_{bT}\right|\Big[\sin^2\theta\Big(\cos(2\phi-\phi_{S_a}+\phi_{S_b})F_{TT}^{\cos(2\phi-\phi_{S_a}+\phi_{S_b})} + \cos(2\phi+\phi_{S_a}-\phi_{S_b})F_{TT}^{\cos(2\phi+\phi_{S_a}-\phi_{S_b})}\Big)\Big]\Big\}$$

where F_{jk}^{i} are the Structure Functions (SFs) connected to the corresponding PDFs. The SFs depend on four variables $P_a\cdot q$, $P_b\cdot q$, $\mathbf{q_T}$ and q^2 or on $\mathbf{q_T}$, q^2 and the Bjorken variables of colliding hadrons, x_a, x_b,

$$x_a = \frac{q^2}{2P_a\cdot q} = \sqrt{\frac{q^2}{s}}e^{y},\quad x_b = \frac{q^2}{2P_b\cdot q} = \sqrt{\frac{q^2}{s}}e^{-y},$$ y is the CM rapidity and

The cross section cannot be measured directly because there is no single beam containing particles with the U, L and T polarization. To measure SFs entering this equation one can use the following procedure: first, to integrate cross section over the azimuthal angle *Φs*, second, following the SIDIS practice, to measure azimuthal asymmetries of the DY pair's production cross sections. The integration over the azimuthal angle *Φ* gives:

$$\sigma_{int} \equiv \frac{d\sigma}{dx_a dx_b d^2q_T d\cos\theta} = \frac{\pi\alpha^2}{2q^2}\times\big(1+\cos^2\theta\big)\Big[F_{UU}^1 + S_{aL}S_{bL}F_{LL}^1$$
$$+\left|\vec{S}_{aT}\right|\left|\vec{S}_{bT}\right|\Big(\cos(\phi_{S_b}-\phi_{S_a})F_{TT}^{\cos(\phi_{S_b}-\phi_{S_a})} + D\cos(\phi_{S_a}+\phi_{S_b})F_{TT}^{\cos(\phi_{S_a}+\phi_{S_b})}\Big)\Big]$$

Drell-Yan studies with SPD.

The PDFs studies via Fourier analysis to the measured asymmetries.

$$A_{UU} \equiv \frac{\sigma^{00}}{\sigma^{00}_{int}} = \frac{1}{2\pi}(1 + D\cos 2\phi A_{UU}^{\cos 2\phi})$$

$$A_{LU} \equiv \frac{\sigma^{\rightarrow 0} - \sigma^{\leftarrow 0}}{\sigma^{\rightarrow 0}_{int} + \sigma^{\leftarrow 0}_{int}} = \frac{|S_{aL}|}{2\pi} D \sin 2\phi A_{LU}^{\sin 2\phi}$$

$$A_{UL} \equiv \frac{\sigma^{0\rightarrow} - \sigma^{0\leftarrow}}{\sigma^{0\rightarrow}_{int} + \sigma^{0\leftarrow}_{int}} = \frac{|S_{bL}|}{2\pi} D \sin 2\phi A_{UL}^{\sin 2\phi}$$

$$A_{TU} \equiv \frac{\sigma^{\uparrow 0} - \sigma^{\downarrow 0}}{\sigma^{\uparrow 0}_{int} + \sigma^{\downarrow 0}_{int}} = \frac{|\vec{S}_{aT}|}{2\pi}\left[A_{TU}^{\sin(\phi-\phi_{S_a})} \sin(\phi - \phi_{S_a}) + D\left(A_{TU}^{\sin(3\phi-\phi_{S_a})} \sin(3\phi - \phi_{S_a}) + A_{TU}^{\sin(\phi+\phi_{S_a})} \sin(\phi + \phi_{S_a}) \right)\right]$$

$$A_{UT} \equiv \frac{\sigma^{0\uparrow} - \sigma^{0\downarrow}}{\sigma^{0\uparrow}_{int} + \sigma^{0\downarrow}_{int}} = \frac{|\vec{S}_{bT}|}{2\pi}\left[A_{UT}^{\sin(\phi-\phi_{S_b})} \sin(\phi - \phi_{S_b}) + D\left(A_{UT}^{\sin(3\phi-\phi_{S_b})} \sin(3\phi - \phi_{S_b}) + A_{UT}^{\sin(\phi+\phi_{S_b})} \sin(\phi + \phi_{S_b}) \right)\right]$$

$$A_{LL} \equiv \frac{\sigma^{\rightarrow\rightarrow} + \sigma^{\leftarrow\leftarrow} - \sigma^{\rightarrow\leftarrow} - \sigma^{\leftarrow\rightarrow}}{\sigma^{\rightarrow\rightarrow}_{int} + \sigma^{\leftarrow\leftarrow}_{int} + \sigma^{\rightarrow\leftarrow}_{int} + \sigma^{\leftarrow\rightarrow}_{int}} = \frac{|S_{aL} S_{bL}|}{2\pi}\left(A_{LL}^{1} + D A_{LL}^{\cos 2\phi} \cos 2\phi \right)$$

$$A_{TL} \equiv \frac{\sigma^{\uparrow\rightarrow} + \sigma^{\downarrow\leftarrow} - \sigma^{\downarrow\rightarrow} - \sigma^{\uparrow\leftarrow}}{\sigma^{\uparrow\rightarrow}_{int} + \sigma^{\downarrow\leftarrow}_{int} + \sigma^{\downarrow\rightarrow}_{int} + \sigma^{\uparrow\leftarrow}_{int}} = \frac{|\vec{S}_{aT}| S_{bL}}{2\pi}\left[A_{TL}^{\cos(\phi-\phi_{S_a})} \cos(\phi - \phi_{S_a}) + D\begin{pmatrix} A_{TL}^{\cos(3\phi-\phi_{S_a})} \cos(3\phi - \phi_{S_a}) \\ + A_{TL}^{\cos(\phi+\phi_{S_a})} \cos(\phi + \phi_{S_a}) \end{pmatrix}\right]$$

$$A_{LT} \equiv \frac{\sigma^{\rightarrow\uparrow} + \sigma^{\leftarrow\downarrow} - \sigma^{\rightarrow\downarrow} - \sigma^{\leftarrow\uparrow}}{\sigma^{\rightarrow\uparrow}_{int} + \sigma^{\leftarrow\downarrow}_{int} + \sigma^{\rightarrow\downarrow}_{int} + \sigma^{\leftarrow\uparrow}_{int}} = \frac{S_{aL} |\vec{S}_{bT}|}{2\pi}\left[A_{LT}^{\cos(\phi-\phi_{S_b})} \cos(\phi - \phi_{S_b}) + D\begin{pmatrix} A_{LT}^{\cos(3\phi-\phi_{S_b})} \cos(3\phi - \phi_{S_b}) \\ + A_{LT}^{\cos(\phi+\phi_{S_b})} \cos(\phi + \phi_{S_b}) \end{pmatrix}\right]$$

$$A_{TT} \equiv \frac{\sigma^{\uparrow\uparrow} + \sigma^{\downarrow\downarrow} - \sigma^{\uparrow\downarrow} - \sigma^{\downarrow\uparrow}}{\sigma^{\uparrow\uparrow}_{int} + \sigma^{\downarrow\downarrow}_{int} + \sigma^{\uparrow\downarrow}_{int} + \sigma^{\downarrow\uparrow}_{int}} = \frac{|\vec{S}_{aT}||\vec{S}_{bT}|}{2\pi}\Big[A_{TT}^{\cos(2\phi-\phi_{S_a}-\phi_{S_b})} \cos(2\phi - \phi_{S_a} - \phi_{S_b}) + A_{TT}^{\cos(\phi_{S_b}-\phi_{S_a})} \cos(\phi_{S_b} - \phi_{S_a})$$
$$+ D\Big(A_{TT}^{\cos(\phi_{S_b}+\phi_{S_a})} \cos(\phi_{S_a} + \phi_{S_b}) + A_{TT}^{\cos(4\phi-\phi_{S_a}-\phi_{S_b})} \cos(4\phi - \phi_{S_a} - \phi_{S_b})$$
$$+ A_{TT}^{\cos(2\phi-\phi_{S_a}+\phi_{S_b})} \cos(2\phi - \phi_{S_a} + \phi_{S_b}) + A_{TT}^{\cos(2\phi+\phi_{S_a}-\phi_{S_b})} \cos(2\phi + \phi_{S_a} - \phi_{S_b}) \Big)\Big]$$

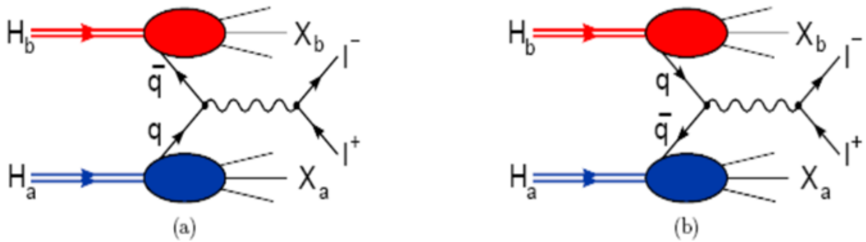
The azimuthal asymmetries can be calculated as ratios of cross sections differences to the sum of the integrated over Φ cross sections.

The azimuthal distribution of MMT-DY pair's produced in non-polarized hadron collisions, A_{UU}, and azimuthal asymmetries of the cross sections in polarized hadron collisions, A_{jk}, are given by relations shown left.

Applying the Fourier analysis to the measured asymmetries, one can separate each of all ratios entering previous slide. The extraction of different TMD PDFs from those ratios is a task of the global theoretical analysis (a challenge for the theoretical community) since each of the SFs a result of convolutions of different TMD PDFs in the quark transverse momentum space. For this purpose one needs either to assume a factorization of the transverse momentum dependence for each TMD PDFs, having definite mathematic form (usually Gaussian) with some parameters to be fitted (M. Anselmino et al., arXiv:1304.7691 [hep-ph]), or to transfer to impact parameter representation space and to use the Bessel weighted TMD PDFs (Daniel Boer, Leonard Gamberg, Bernhard Musch, Alexei Prokudin, JHEP 1110 (2011) 021, [arXiv:1107.5294])

Drell-Yan studies with SPD.

Studies of PDFs via integrated/weighted asymmetries.



$$A_{UT}^{w[\sin(\phi+\phi_S)]} = \frac{\int d\Omega\, d\phi_S \sin(\phi+\phi_S)\left[d\sigma^{\uparrow} - d\sigma^{\downarrow}\right]}{\int d\Omega\, d\phi_S \left[d\sigma^{\uparrow} + d\sigma^{\downarrow}\right]/2} = -\frac{1}{2}\frac{C\left[\frac{\vec{h}\cdot\vec{k}_{aT}}{M_a} h_1^{\perp} \bar{h}_1\right]}{C\left[f_1 \bar{f}_1\right]},$$

$$A_{UT}^{w[\sin(\phi-\phi_S)]} = \frac{\int d\Omega\, d\phi_S \sin(\phi-\phi_S)\left[d\sigma^{\uparrow} - d\sigma^{\downarrow}\right]}{\int d\Omega\, d\phi_S \left[d\sigma^{\uparrow} + d\sigma^{\downarrow}\right]/2} = \frac{1}{2}\frac{C\left[\frac{\vec{h}\cdot\vec{k}_{bT}}{M_b} f_1 \bar{f}_{1T}^{\perp}\right]}{C\left[f_1 \bar{f}_1\right]},$$

$$A_{UT}^{w[\sin(3\phi-\phi_S)]} = \frac{\int d\Omega\, d\phi_S \sin(3\phi-\phi_S)\left[d\sigma^{\uparrow} - d\sigma^{\downarrow}\right]}{\int d\Omega\, d\phi_S \left[d\sigma^{\uparrow} + d\sigma^{\downarrow}\right]/2} =$$

$$= -\frac{1}{2}\frac{C\left[\frac{2(\vec{h}\cdot\vec{k}_{bT})[2(\vec{h}\cdot\vec{k}_{aT})(\vec{h}\cdot\vec{k}_{bT}) - \vec{k}_{aT}\cdot\vec{k}_{bT}] - \vec{k}_{bT}^2(\vec{h}\cdot\vec{k}_{aT})}{2M_a M_b^2} h_1^{\perp} \bar{h}_{1T}^{\perp}\right]}{C\left[f_1 \bar{f}_1\right]}$$

$$A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]} = \frac{\int d\Omega \int d^2\mathbf{q}_T (|\mathbf{q}_T|/M_p) \sin(\phi+\phi_S)\left[d\sigma^{\uparrow} - d\sigma^{\downarrow}\right]}{\int d\Omega \int d^2\mathbf{q}_T \left[d\sigma^{\uparrow} + d\sigma^{\downarrow}\right]/2}$$

$$= -\frac{\sum_q e_q^2\left[\bar{h}_{1q}^{\perp(1)}(x_p) h_{1q}(x_{p\uparrow}) + (q\leftrightarrow\bar{q})\right]}{\sum_q e_q^2\left[\bar{f}_{1q}(x_p) f_{1q}(x_{p\uparrow}) + (q\leftrightarrow\bar{q})\right]},$$

$$A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]} = \frac{\int d\Omega \int d^2\mathbf{q}_T (|\mathbf{q}_T|/M_p) \sin(\phi-\phi_S)\left[d\sigma^{\uparrow} - d\sigma^{\downarrow}\right]}{\int d\Omega \int d^2\mathbf{q}_T \left[d\sigma^{\uparrow} + d\sigma^{\downarrow}\right]/2}$$

$$= 2\frac{\sum_q e_q^2\left[f_{1T}^{\perp(1)q}(x_{p\uparrow}) f_{1q}(x_p) + (q\leftrightarrow\bar{q})\right]}{\sum_q e_q^2\left[\bar{f}_{1q}(x_{p\uparrow}) f_{1q}(x_p) + (q\leftrightarrow\bar{q})\right]},$$

where

$$h_{1q}^{\perp(1)}(x) = \int d^2k_T \left(\frac{k_T^2}{2M_p^2}\right) h_{1q}^{\perp}(x_p, k_T^2) \quad \text{and} \quad f_{q1T}^{\perp(1)}(x) = \int d^2k_T \left(\frac{k_T^2}{2M_p^2}\right) f_{q1T}^{\perp(1)}(x, k_T^2)$$

The set of asymmetries mentioned above gives the access to all eight leading twist TMD PDFs. However, sometimes one can work with integrated asymmetries. Integrated asymmetries are useful for the express analysis of data and checks of expected relations between asymmetries mentioned above. They are also useful for model estimations and determination of required statistics . Let us consider several examples starting from the case when only one of colliding hadrons (for instance, hadron "b") is transversely polarized. In this case the DY cross section can be reduced to the expression:

$$\frac{d\sigma}{dx_a dx_b d^2\mathbf{q}_T d\Omega} = \frac{\alpha^2}{4Q^2}\Big\{(1+\cos^2\theta)\, C\left[f_1 \bar{f}_1\right]$$

$$+ \sin^2\theta \cos 2\phi\, C\left[\frac{2(\vec{h}\cdot\vec{k}_{aT})(\vec{h}\cdot\vec{k}_{bT}) - \vec{k}_{aT}\cdot\vec{k}_{bT}}{M_a M_b} h_1^{\perp} \bar{h}_1^{\perp}\right]$$

$$+ |S_{bT}|\Big[(1+\cos^2\theta)\sin(\phi-\phi_{S_b})\, C\left[\frac{\vec{h}\cdot\vec{k}_{bT}}{M_b} f_1 \bar{f}_{1T}^{\perp}\right] - \sin^2\theta \sin(\phi+\phi_{S_b})\, C\left[\frac{\vec{h}\cdot\vec{k}_{aT}}{M_a} h_1^{\perp} \bar{h}_1\right]$$

$$- \sin^2\theta \sin(3\phi-\phi_{S_b})\, C\left[\frac{2(\vec{h}\cdot\vec{k}_{bT})[2(\vec{h}\cdot\vec{k}_{aT})(\vec{h}\cdot\vec{k}_{bT}) - \vec{k}_{aT}\cdot\vec{k}_{bT}] - \vec{k}_{bT}^2(\vec{h}\cdot\vec{k}_{aT})}{2M_a M_b^2} h_1^{\perp} \bar{h}_{1T}^{\perp}\right]\Big]\Big\}$$

Drell-Yan studies with SPD.

Studies of PDFs via integrated/weighted asymmetries.

The integrated and additionally q_T-weighted asymmetries $A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]}$ and $A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]}$ provide access to the first moments of the Boer-Mulders, $h_{1q}^{\perp}(x,k_T^2)$ and Sivers, $f_{q1T}^{\perp(1)}(x,k_T^2)$

$$A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{x_p\gg x_{p\uparrow}} \approx 2\frac{\bar{f}_{1uT}^{\perp(1)}(x_{p\uparrow})}{\bar{f}_{1u}(x_{p\uparrow})} \quad ; \quad A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{x_p\gg x_{p\uparrow}} \approx -\frac{h_{1u}^{\perp(1)}(x_p)\bar{h}_{1u}(x_{p\uparrow})}{f_{1u}(x_p)\bar{f}_{1u}(x_{p\uparrow})} \quad A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{x_p\ll x_{p\uparrow}} \approx 2\frac{f_{1uT}^{\perp(1)}(x_{p\uparrow})}{f_{1u}^{\perp(1)}(x_{p\uparrow})} \quad ; \quad A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{x_p\ll x_{p\uparrow}} \approx -\frac{\bar{h}_{1u}^{\perp(1)}(x_p)h_{1u}(x_{p\uparrow})}{\bar{f}_{1u}(x_p)f_{1u}(x_{p\uparrow})}.$$

So far the pp-collisions have been considered. At NICA the pd- and dd-collisions will be investigated as well. As it is known from COMPASS experiment, the SIDIS asymmetries on polarized deuterons are consisted with zero. At NICA one can expect that asymmetries

$$A_{UT}^{w\left[\sin(\phi\pm\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{pD^\uparrow}, \quad A_{UT}^{w\left[\sin(\phi\pm\phi_S)\frac{q_T}{M_N}\right]}\Bigg|_{DD^\uparrow}$$

also will be consistent with zero (subject of tests).

But asymmetries in *Dp*↑ collisions are expected to be non-zero. In the limiting cases $x_D \gg x_{p^\uparrow}$ and $x_D \ll x_{p^\uparrow}$ these asymmetries (**accessible only at NICA**)

$$A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]}(x_D \gg x_{p\uparrow})\Bigg|_{Dp\uparrow\to l^+l^-X} \approx \frac{4\,\bar{f}_{1uT}^{\perp(1)}(x_{p\uparrow}) + \bar{f}_{1dT}^{\perp(1)}(x_{p\uparrow})}{4\,\bar{f}_{1u}^{\perp(1)}(x_{p\uparrow}) + \bar{f}_{1d}^{\perp(1)}(x_{p\uparrow})},$$

$$A_{UT}^{w\left[\sin(\phi-\phi_S)\frac{q_T}{M_N}\right]}(x_D \ll x_{p\uparrow})\Bigg|_{Dp\uparrow\to l^+l^-X} \approx 2\frac{4\,f_{1uT}^{\perp(1)}(x_{p\uparrow}) + f_{1dT}^{\perp(1)}(x_{p\uparrow})}{4\,f_{1u}^{\perp(1)}(x_{p\uparrow}) + f_{1d}^{\perp(1)}(x_{p\uparrow})},$$

$$A_{TT}^{w[\cos(\phi_{Sb}+\phi_{Sa})q_T/M]} \equiv A_{TT}^{int} = \frac{\sum_q e_q^2\left(\bar{h}_{1q}(x_1)h_{1q}(x_2)+(x_1\leftrightarrow x_2)\right)}{\sum_q e_q^2\left(\bar{f}_{1q}(x_1)f_{1q}(x_2)+(x_1\leftrightarrow x_2)\right)}.$$

$$A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]}(x_D \gg x_{p\uparrow})\Bigg|_{Dp\uparrow\to l^+l^-X} \approx -\frac{[h_{1u}^{\perp(1)}(x_D)+h_{1d}^{\perp(1)}(x_D)][4\bar{h}_{1u}(x_{p\uparrow})+\bar{h}_{1d}(x_{p\uparrow})]}{[f_{1u}(x_D)+f_{1d}(x_D)][4\,\bar{f}_{1u}(x_{p\uparrow})+\bar{f}_{1d}(x_{p\uparrow})]},$$

$$A_{UT}^{w\left[\sin(\phi+\phi_S)\frac{q_T}{M_N}\right]}(x_D \ll x_{p\uparrow})\Bigg|_{Dp\uparrow\to l^+l^-X} \approx -\frac{[\bar{h}_{1u}^{\perp(1)}(x_D)+\bar{h}_{1d}^{\perp(1)}(x_D)][4h_{1u}(x_{p\uparrow})+h_{1d}(x_{p\uparrow})]}{[\bar{f}_{1u}(x_D)+\bar{f}_{1d}(x_D)][4\,f_{1u}(x_{p\uparrow})+f_{1d}(x_{p\uparrow})]}.$$