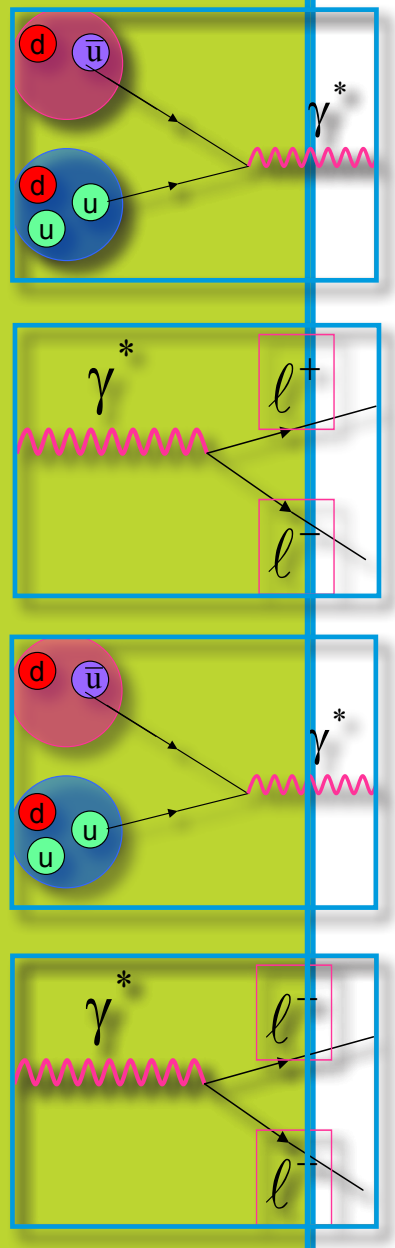


Polarized Drell-Yan measurements at COMPASS

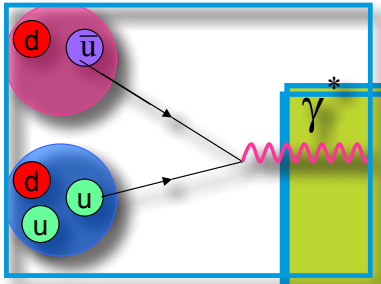
M. Chiosso, University of Torino and INFN
on behalf of the COMPASS Collaboration

Transversity 2014 - Chia (Cagliari)
09 - 13 June 2014

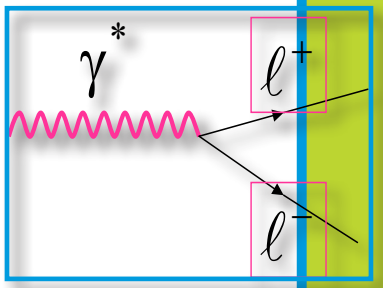
Countdown

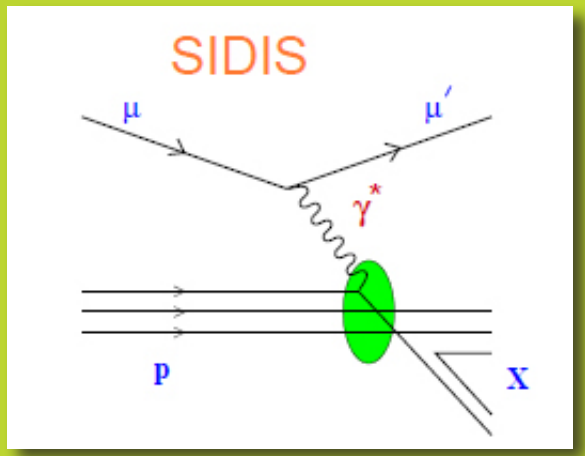
122 d - 4 h - 30′

Single polarized Drell-Yan

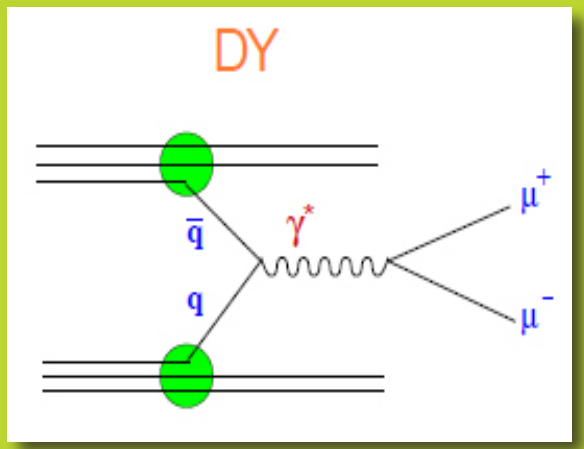


Transversity and other TMD PDFs can be accessed both from semi-inclusive DIS (SIDIS) and from the Drell-Yan process (DY).

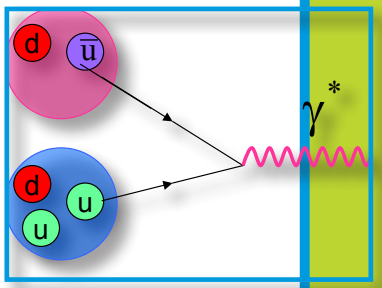


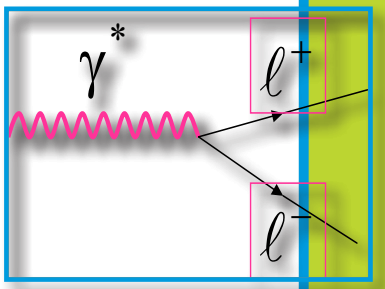


the amplitudes of azimuthal modulations are convolutions of PDFs and FFs

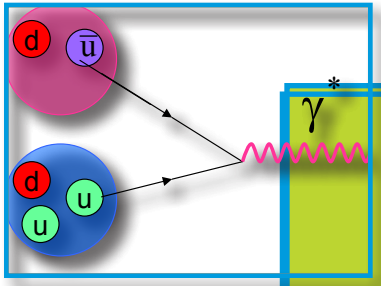


the amplitudes of azimuthal modulations are convolutions of PDFs only

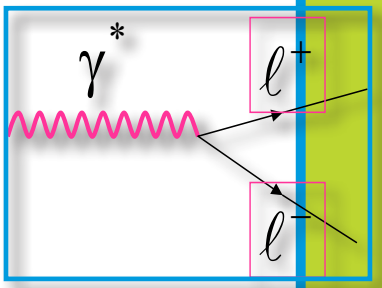


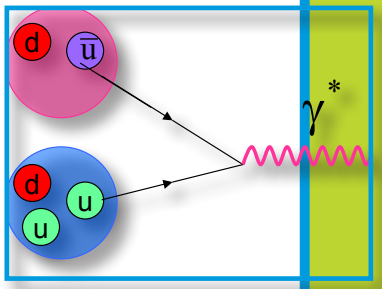


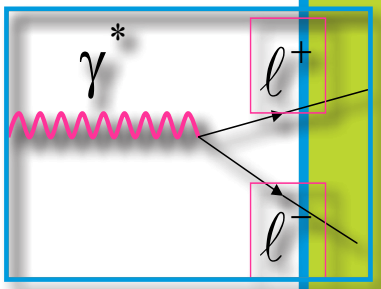
Single polarized Drell-Yan



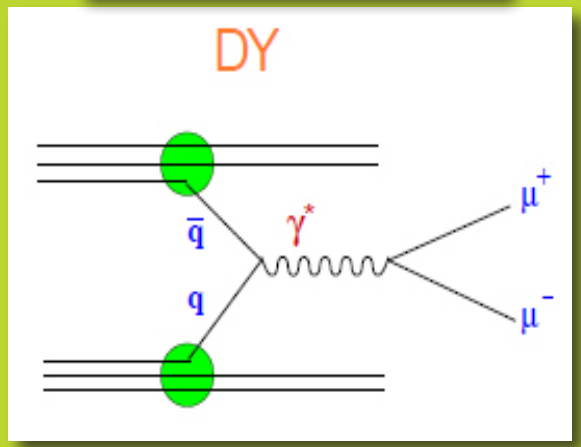
@COMPASS





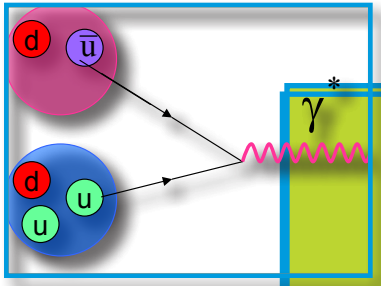


$$\pi^- + p^\uparrow \rightarrow \mu^+\mu^- + X$$



π^- beam at 190 GeV/c on a transversely polarized proton target (NH_3)

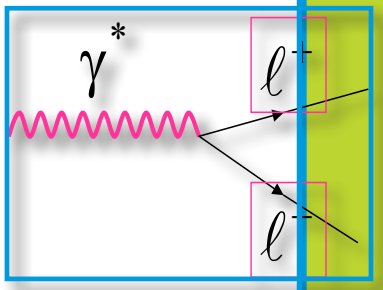
Single polarized Drell-Yan

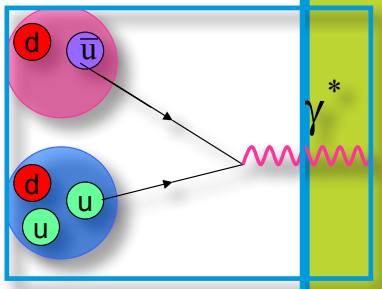


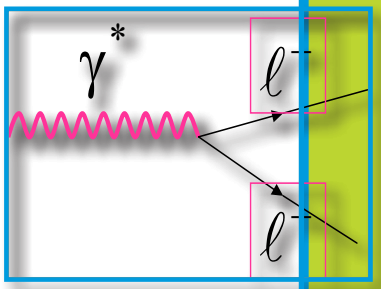
Arnold, Metz and Schlegel derived the full expression of the Drell-Yan cross-section, including unpolarized,transversely and longitudinally polarized terms [S. Arnold et al, Phys.Rev. D79 (2009)034005].

In single polarized DY, with transversely polarized target nucleons, the general expression of the **cross-section** (LO) is:

$$\frac{d\sigma}{d^4q d\Omega} = \frac{\alpha_{em}^2}{Fq^2}\hat{\sigma}_U\{(1 + D_{[\sin^2\theta]}A_U^{\cos 2\phi}\cos 2\phi) + |\vec{S}_T|[A_T^{\sin\phi_S}\sin\phi_S + D_{[\sin^2\theta]}(A_T^{\sin(2\phi+\phi_S)}\sin(2\phi+\phi_S) + A_T^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S))]\}$$



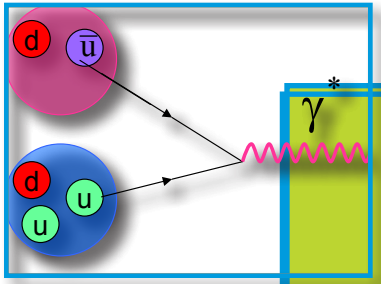




A: azimuthal asymmetries; D: depolarization factor; S: target spin components; F: flux of incoming hadrons; σ_U: part of the cross-section surviving integration over ϕ and ϕ_S

ϕ_S : azimuthal angle of transverse target spin S_T in the target rest frame
ϕ : azimuthal angle of the lepton momenta in the Collins-Soper frame

Single Polarized Drell-Yan

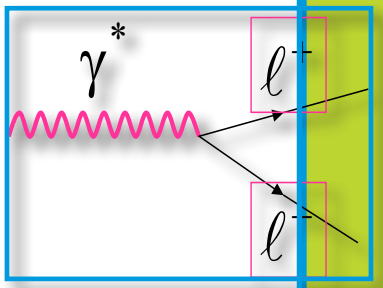


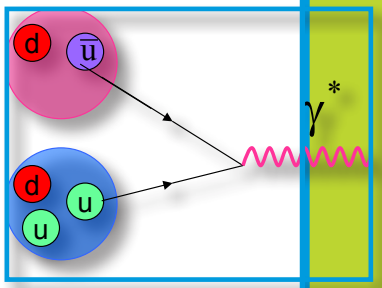
$A_U^{\cos 2\phi}$ gives access to the Boer-Mulders functions of the beam hadron and of the target nucleon

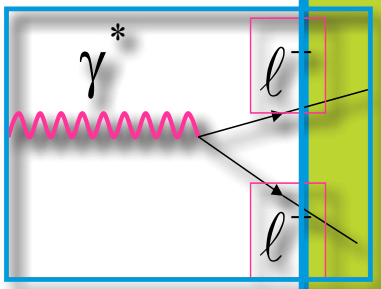
$A_T^{\sin\phi_S}$ to the Sivers function of the target nucleon

$A_T^{\sin(2\phi+\phi_S)}$ to the Boer-Mulders function of the beam hadron and to the pretzelosity function of the target nucleon

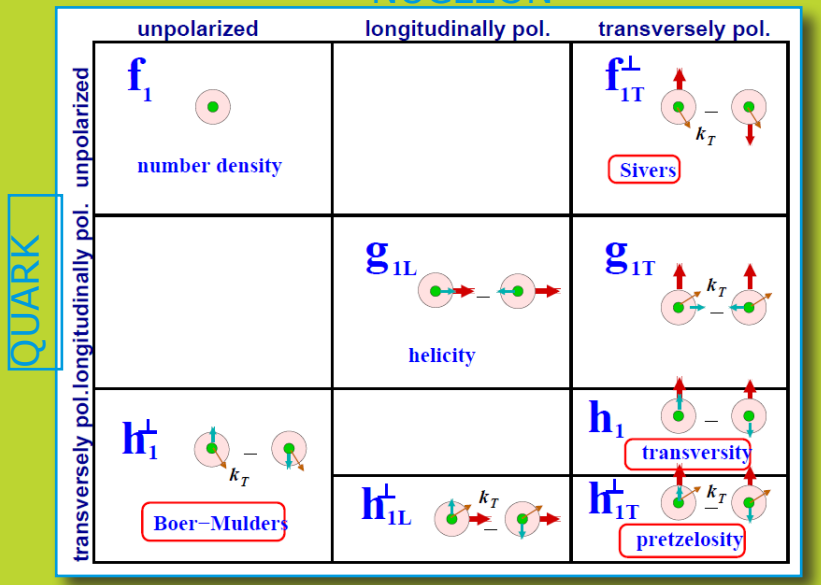
$A_T^{\sin(2\phi-\phi_S)}$ to the Boer-Mulders function of the beam hadron and to the transversity function of the target nucleon



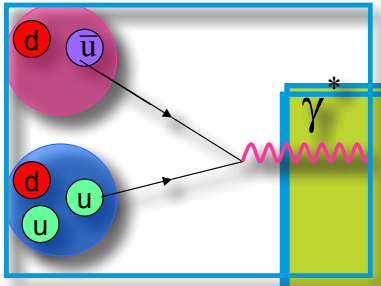




NUCLEON



DY vs SIDIS

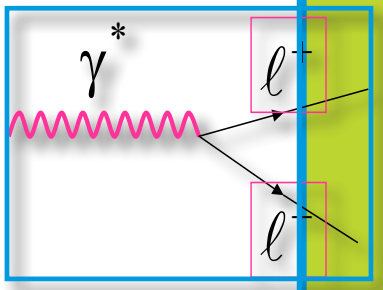


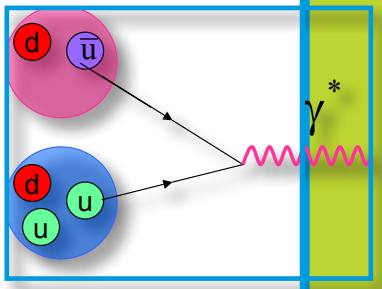
Change of sign of Sivers and Boer-Mulders functions?

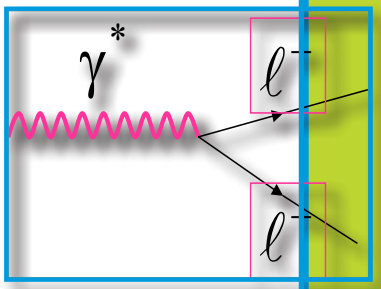
$$f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{DIS} \qquad \text{and} \qquad h_1^{\perp}\Big|_{DY} = -h_1^{\perp}\Big|_{DIS}$$

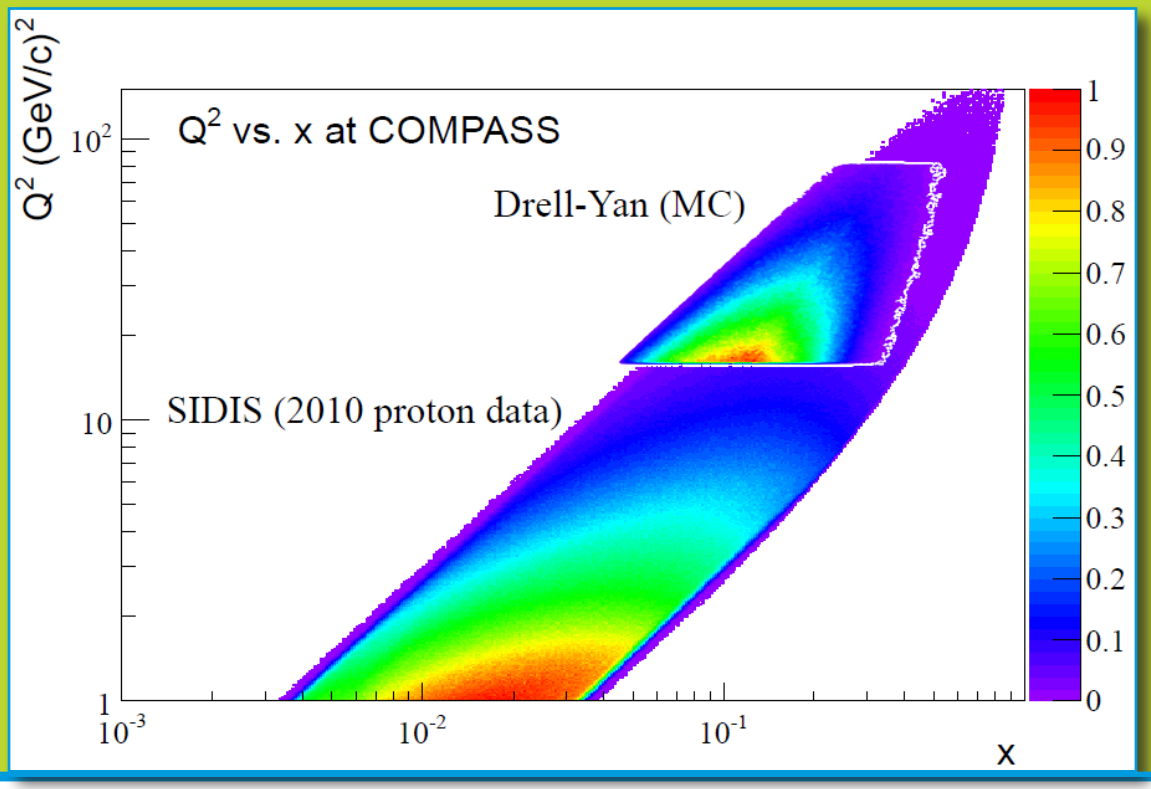
Critical test of universality of TMD factorization approach for the description of SSA.

In **COMPASS**, we have the opportunity to test this sign change using the same spectrometer and a transversely polarized target.

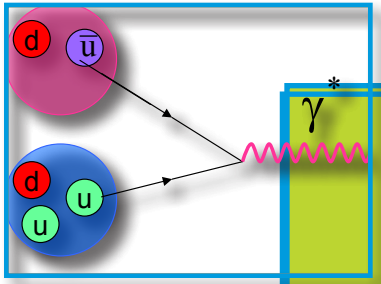






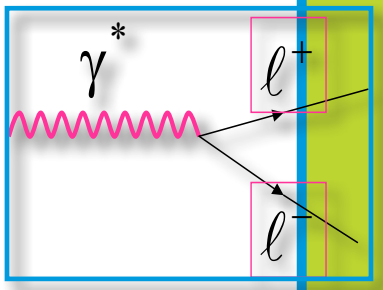


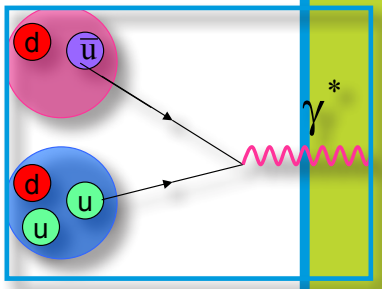
DY vs SIDIS

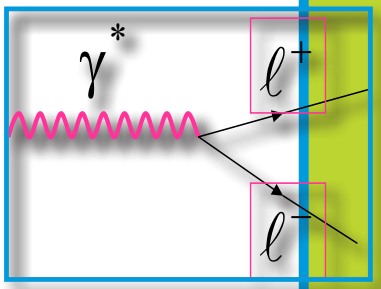


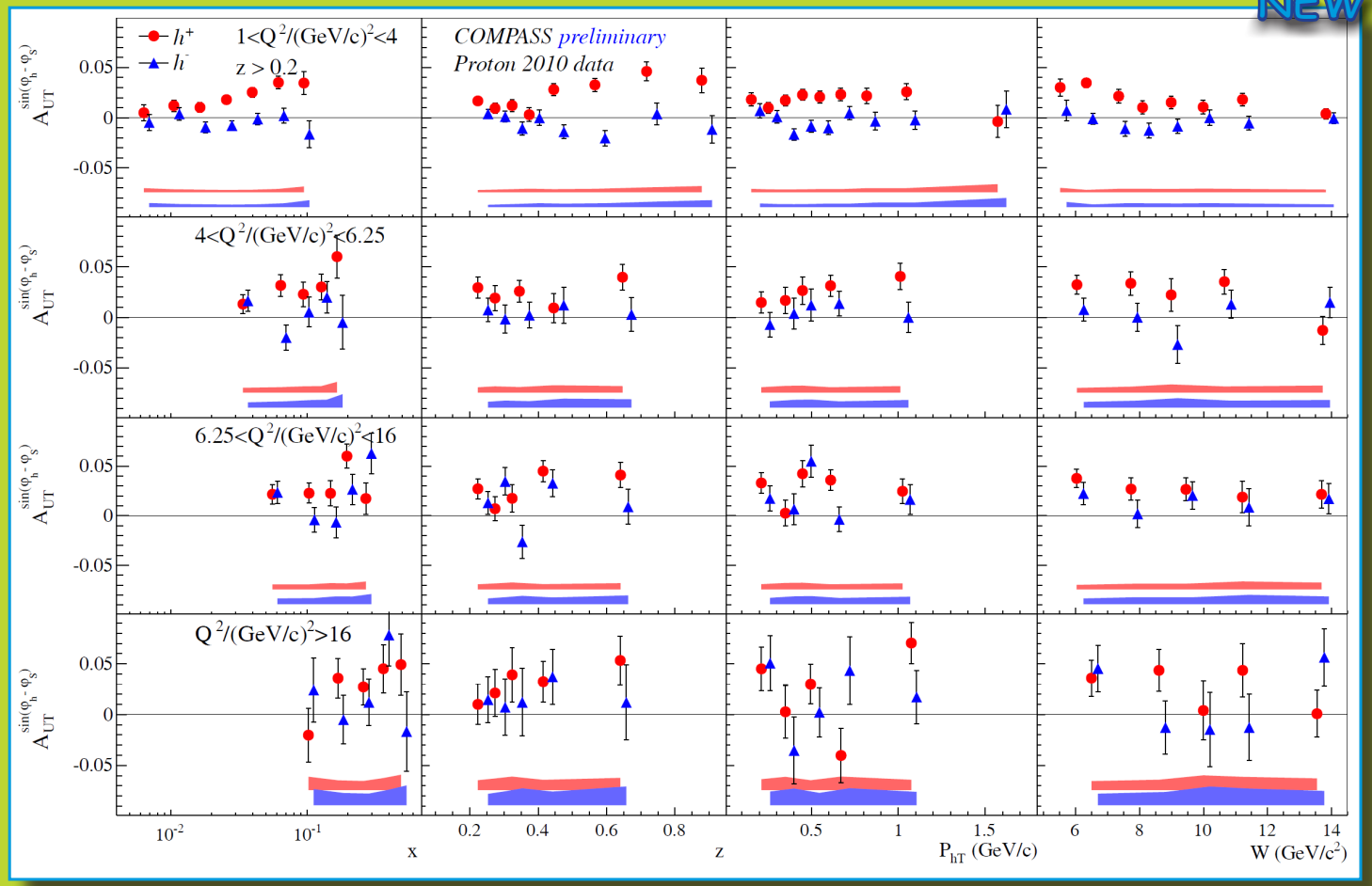
COMPASS SIDIS 2010 proton Data

Sivers in DY-Q^2 range: z > 0.2

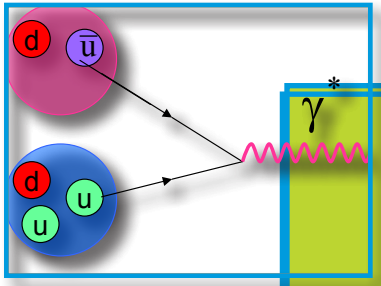


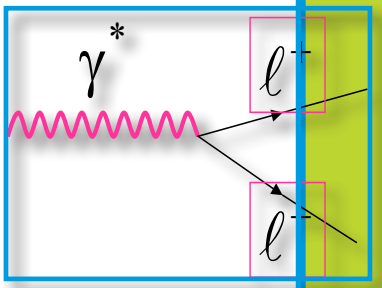


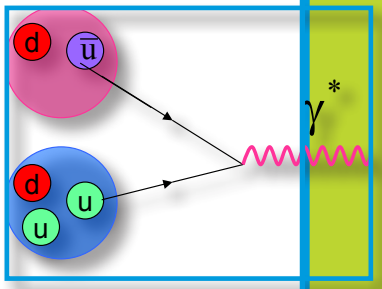


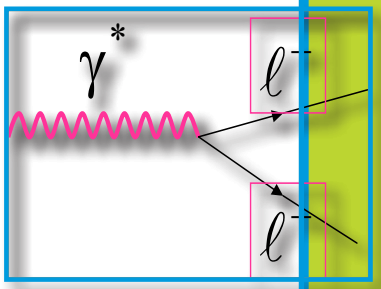


Polarized Drell-Yan experiments









What do we need to access spin dependent PDFs through DY?

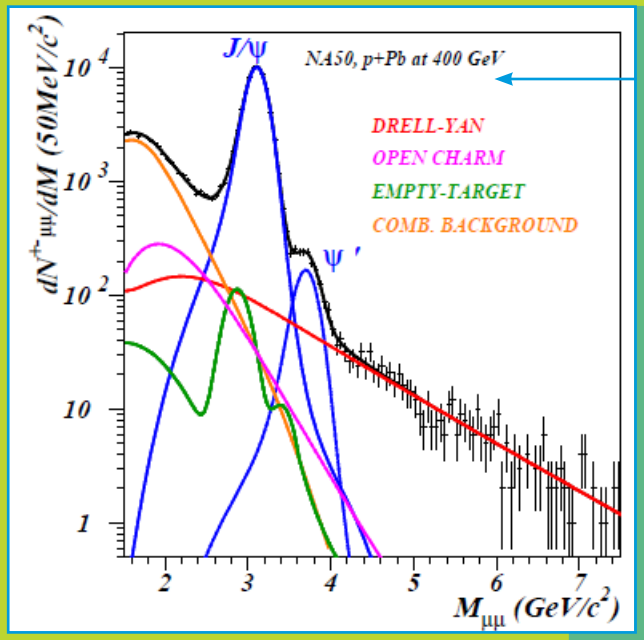
Polarized Drell-Yan experiments:

- High luminosity (DY Cross Section is a fraction of nanobarns) and large angular acceptance

- Sufficiently high energy to access 'safe' background free M range (4 GeV/c^2 < $M_{\mu\mu}$< 9 GeV/c^2)

- Good acceptance in the valence quark range

- Good figure of merit (FoM), which can be represented as a product of the lumino-sity, target polarisation (dilution factor f) and beam (target) polarisation



NA50: p @ 400 GeV/c in a Pb target; I about 10^9 particles/sec

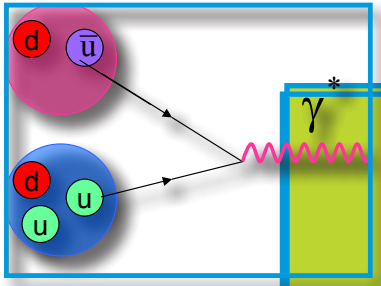
M range 4 < $M_{\mu\mu}$ < 9 GeV/c^2 is the ideal sample to study azimuthal asymmetries in Drell-Yan, due to negligible background contamination.

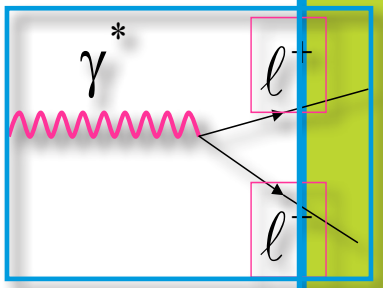
The combinatorial background is kept under control by the presence of a hadron absorber downstream of the target.

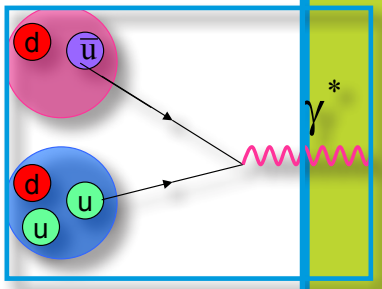
@ COMPASS: π^- @ 190 GeV/c in a NH_3 target;
I up to 10^8 particles/sec:
comb. background 100 times lower (50% of total in intermediate M range 2. < $M_{\mu\mu}$ < 2.5 GeV/c^2)

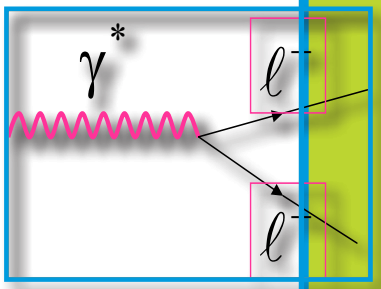
open charm contributes only at 15%

COMPASS Drell-Yan Setup

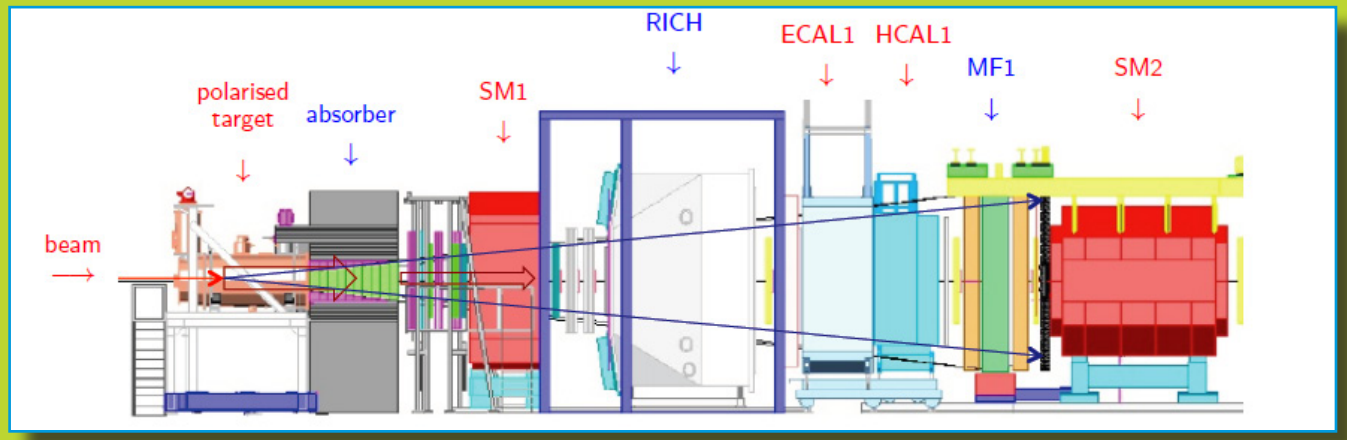




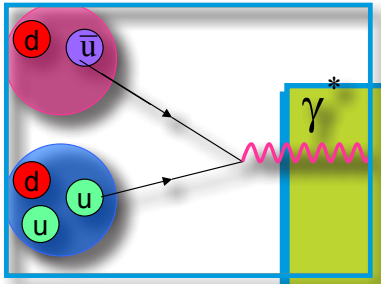




- π^- beam at 190 GeV/c with the intensity up to 1×10^8 particles/second
- Transversely polarized NH_3 2-cell target; target polarization: about 90%; dilution factor: 0.22
- Hadron absorber downstream of the target
- Vertex detector to improve the cell separation of events
- Trigger based on hodoscope signals coincidence, homothetic and pointing to the target



COMPASS Drell-Yan Setup



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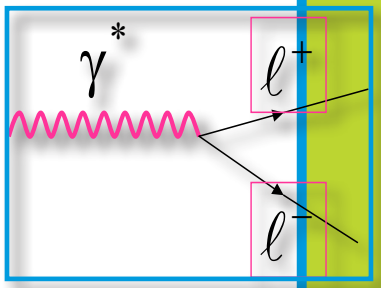
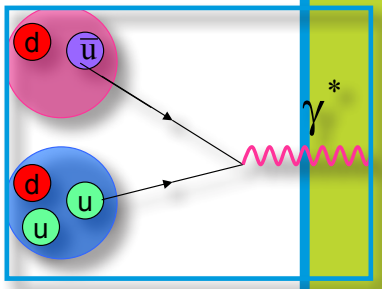
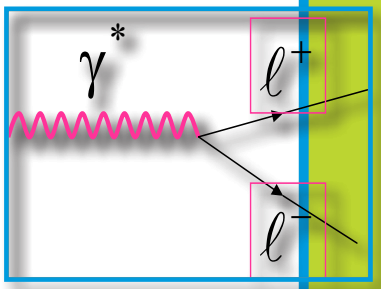
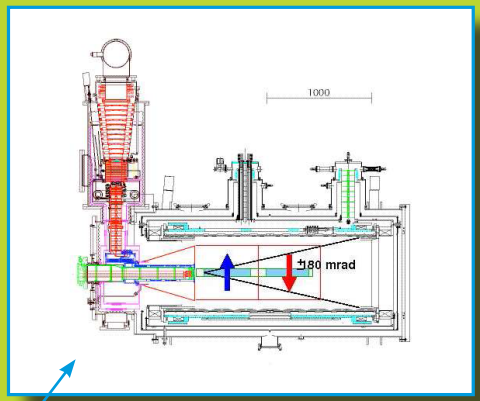
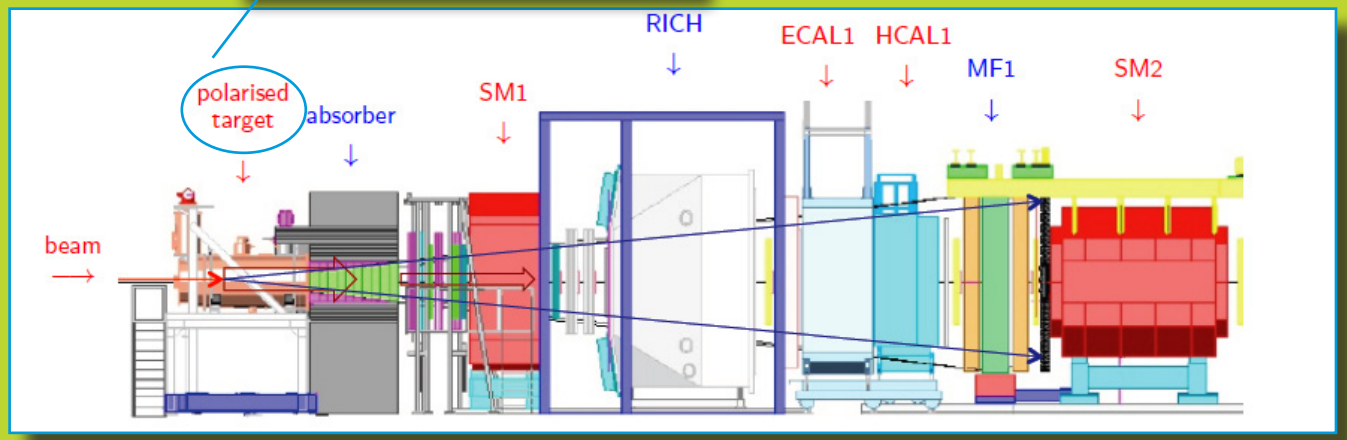


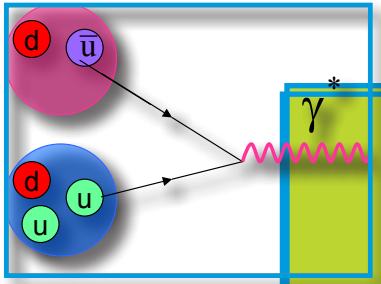








COMPASS Drell-Yan Setup



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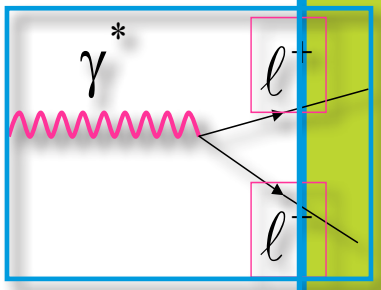
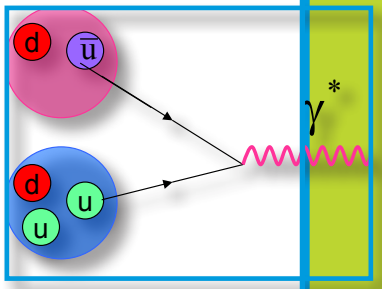
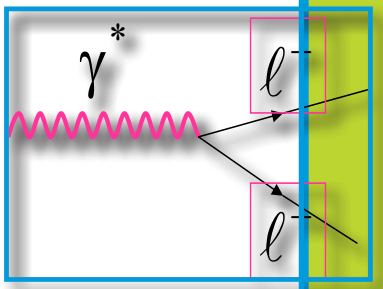
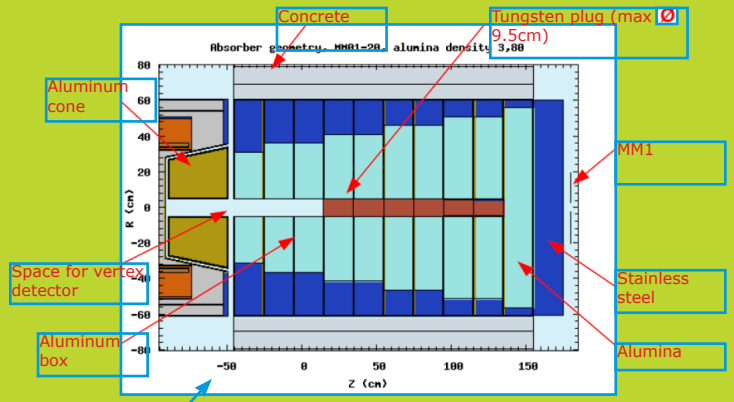
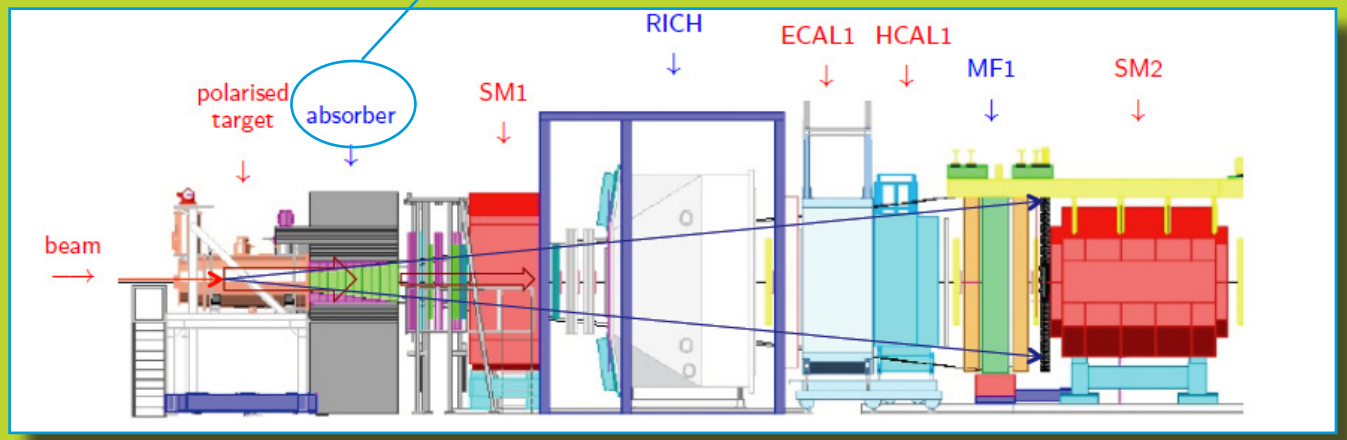


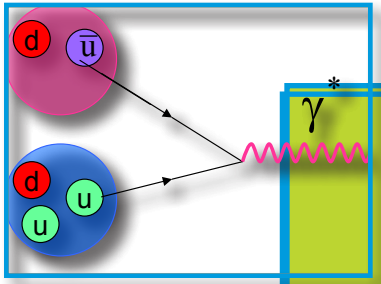




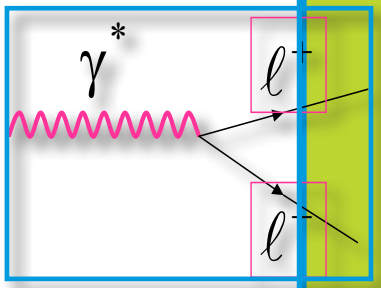


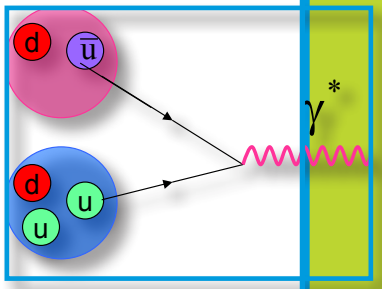


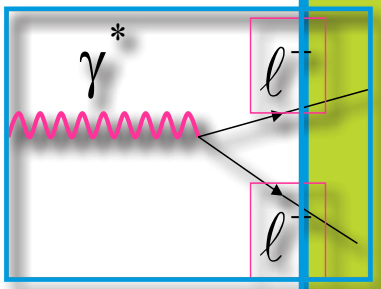
COMPASS Drell-Yan Setup



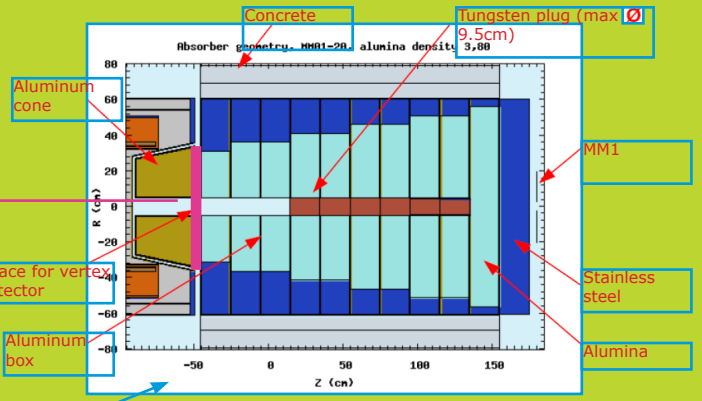
- π^- beam at 190 GeV/c with the intensity up to 1×10^8 particles/second
- Transversely polarized NH_3 2-cell target; target polarization: about 90%; dilution factor: 0.22
- Hadron absorber downstream of the target
- **Vertex detector to improve the cell separation of events**
- Trigger based on hodoscope signals coincidence, homothetic and pointing to the target

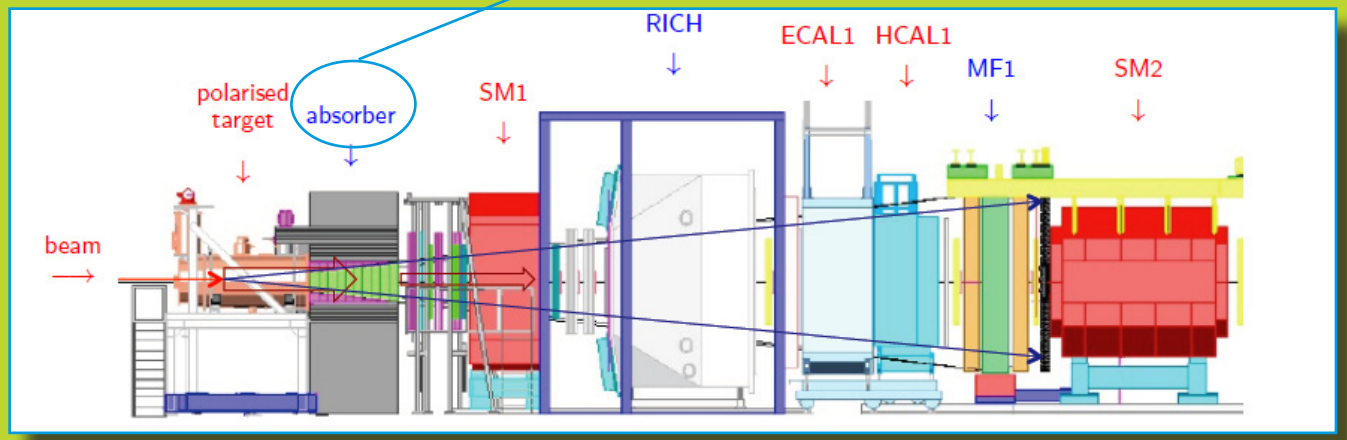




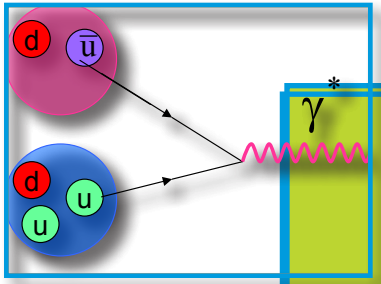


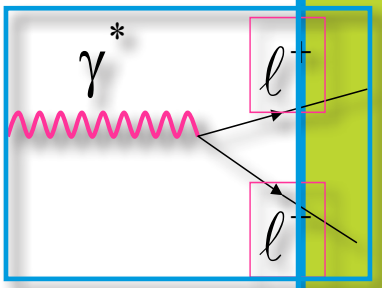
vertex detector

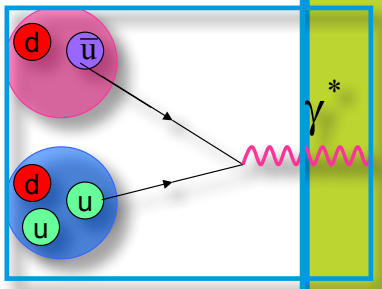


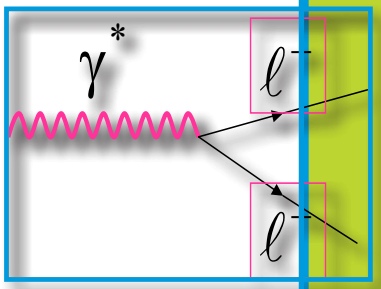


The absorber

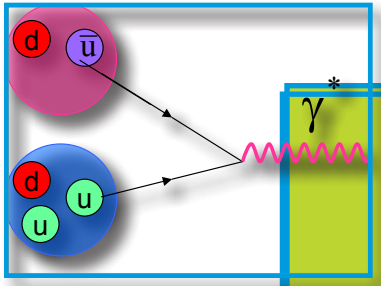


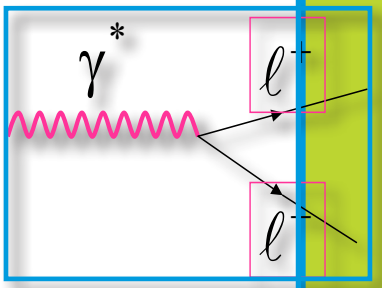


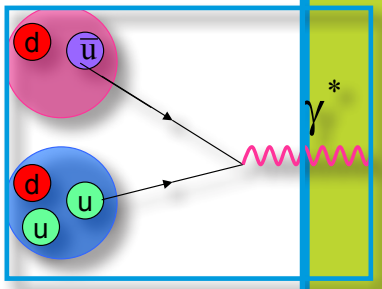


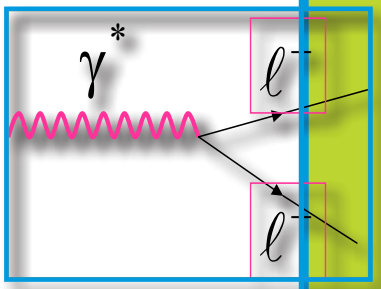


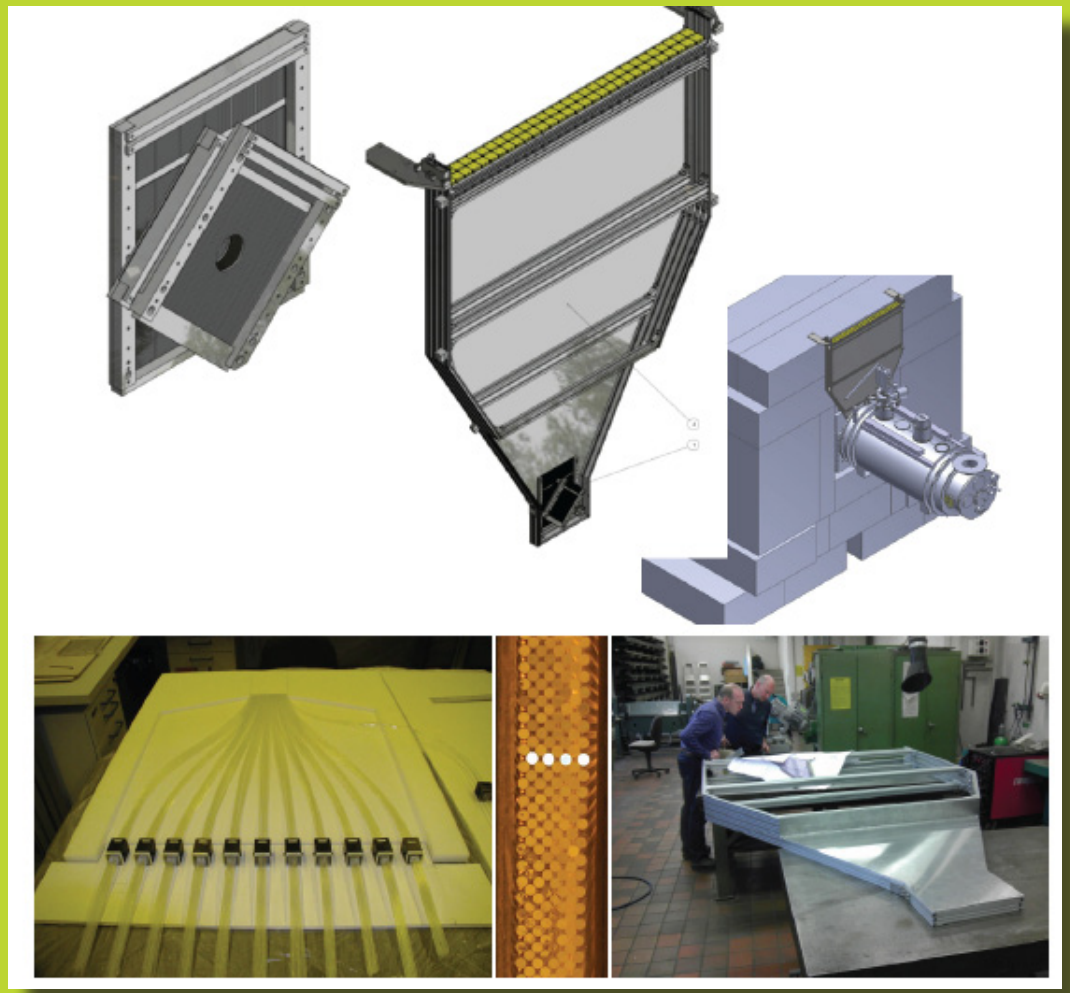
The vertex detector



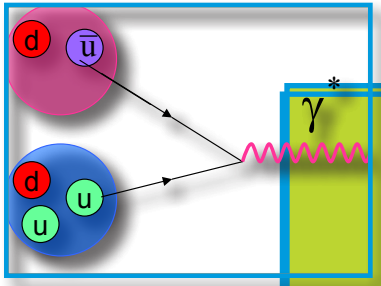


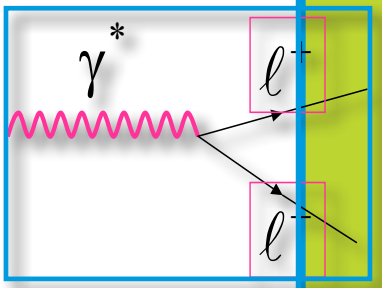


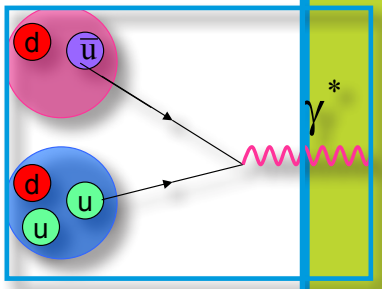


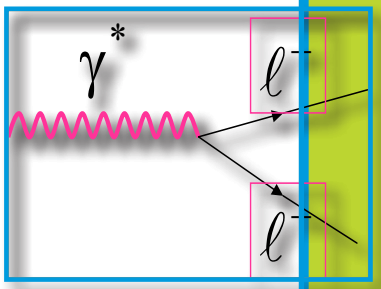


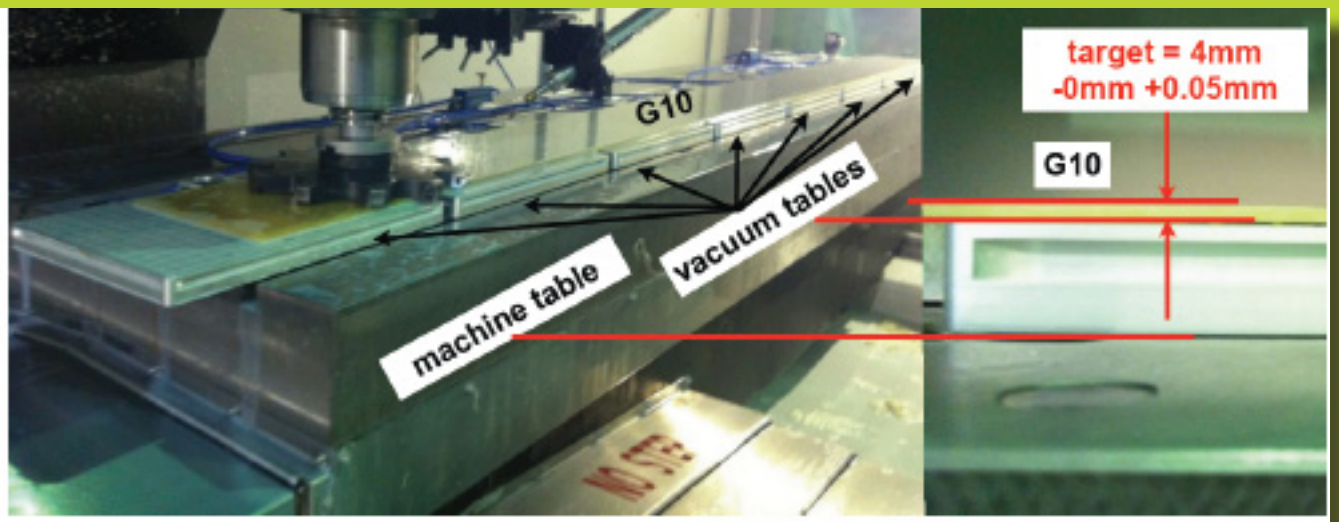
The DC5 chamber



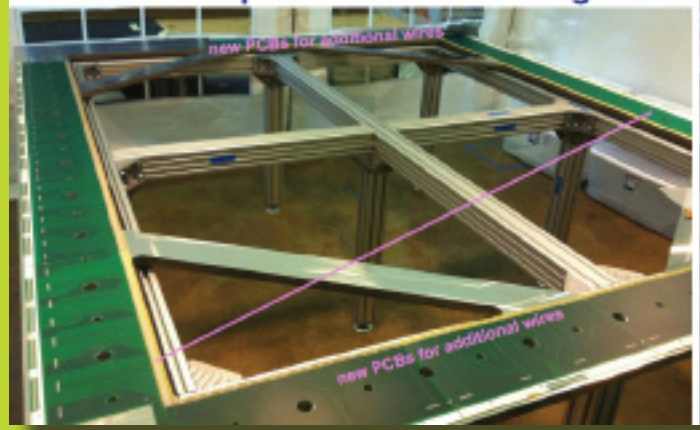




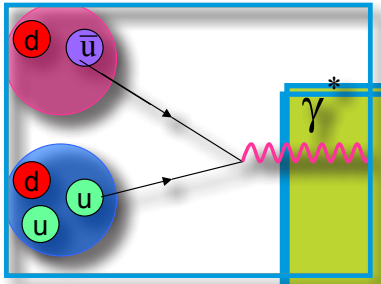




PCBs of the U-plane on the stiffening frame



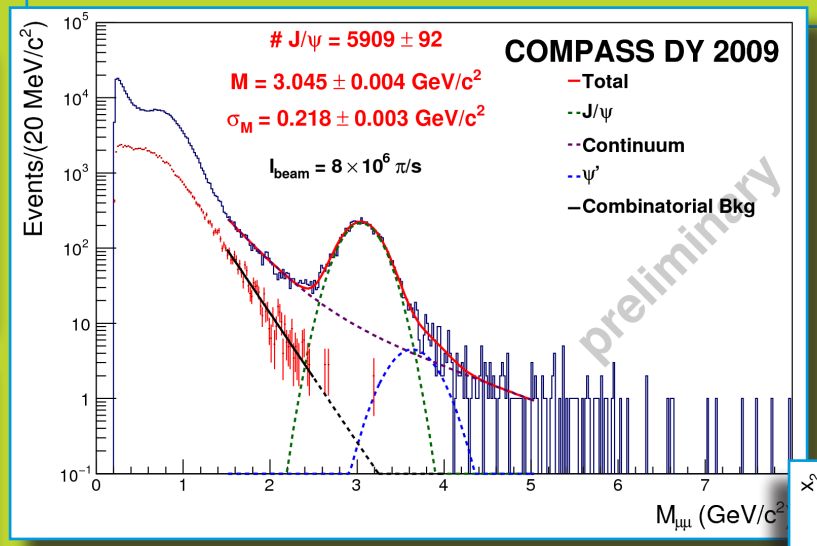
Feasibility



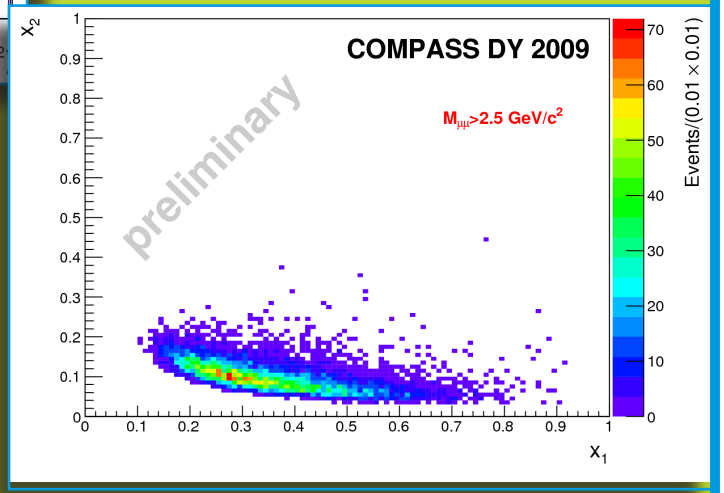
2009 3-days beam test

π^- beam of 160 GeV/c on 2-cell polyethylene target. Setup including a prototype hadron absorber and a beam plug

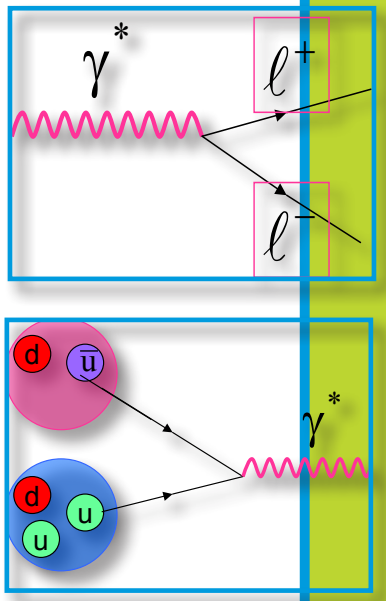
Data taken without the optimised dimuon trigger with target pointing capability

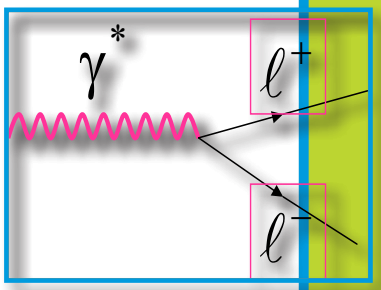


Hadron absorber keeps combinatorial background under control
(at beam intensity lower than nominal by factor 10)

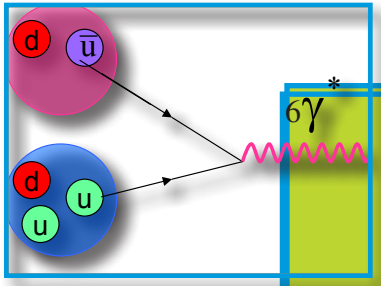


Good acceptance in the valence quark region



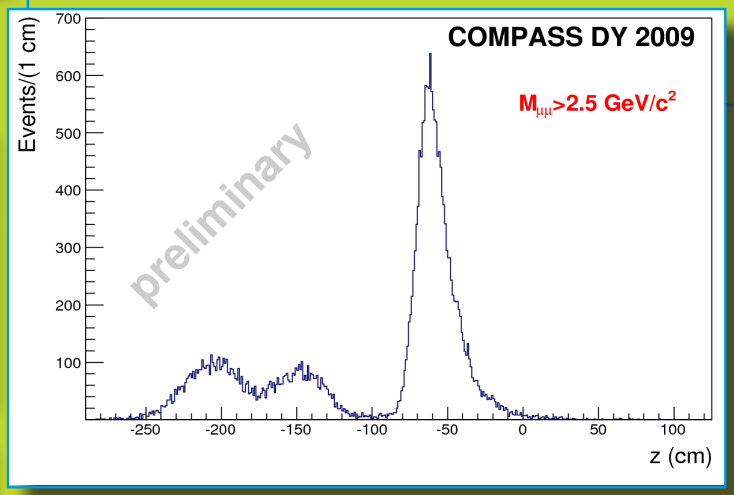


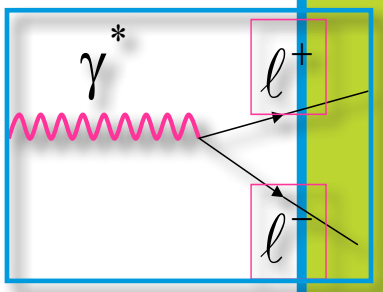
Feasibility

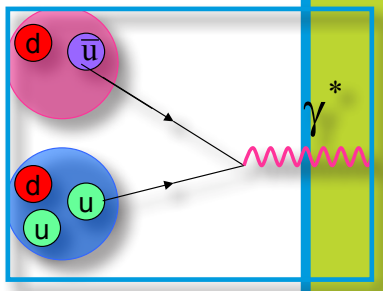


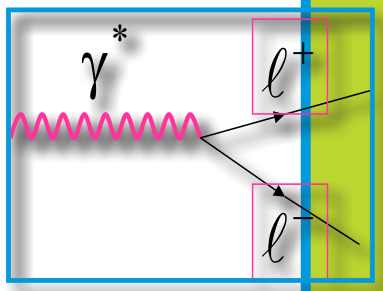
2009 3-days beam test

The vertex distribution from 2009 clearly shows the dimuon events originated in each of the target cells, as well as those produced in the tungsten beam plug.



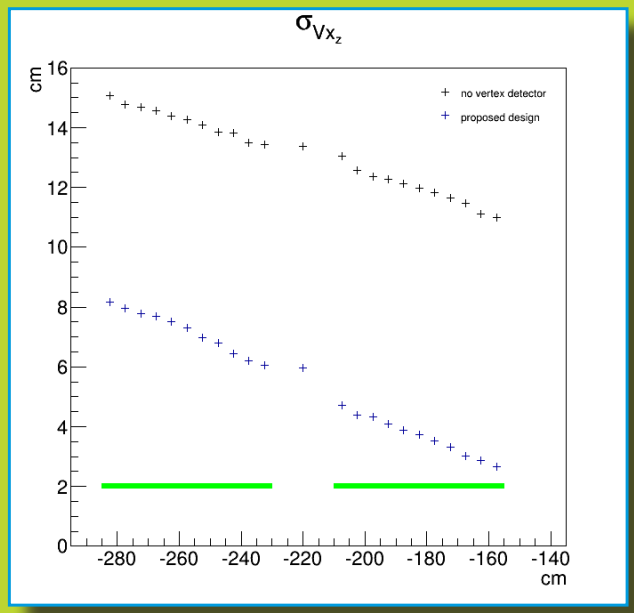




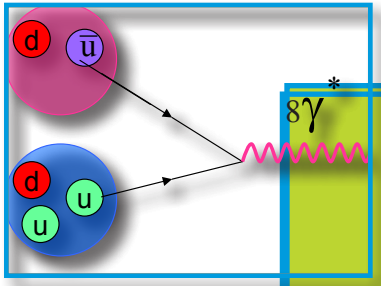


The vertex detector will improve the resolution in vertex position reconstruction

MC simulation:
vertex resolution as function of z coordinate of primary vertex with and without vertex detector



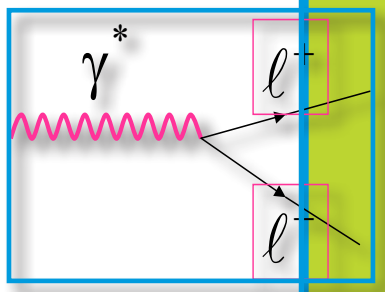
Expected event rates and statistical precision

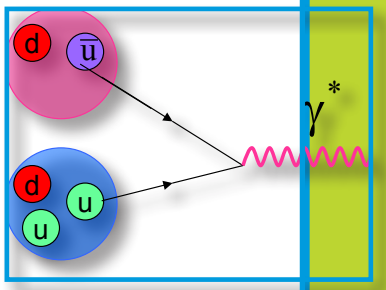


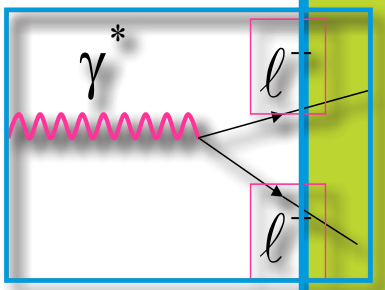
The COMPASS beam availability will be better than foreseen, thanks to a shorter SPS-supercycle. Also the increase in beam intensity contributes to higher event rates.

The new expectation for DY events rate with $4 < M_{\mu\mu} < 9$ GeV/c^2 is now:

- With a beam intensity of $I_{beam} = 10^8$ particles/second, and 9.6s of beam every 34 seconds --> 2000/day.
- In 140 days -->285.000 events.





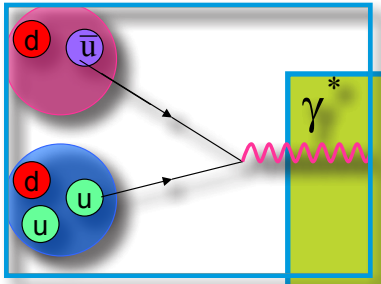


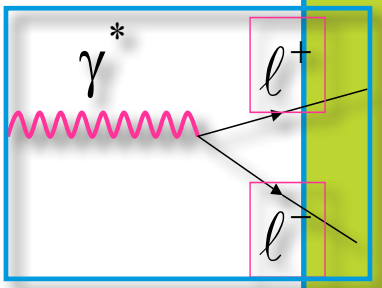
The expected statistical errors in the asymmetries are (in 140 days):

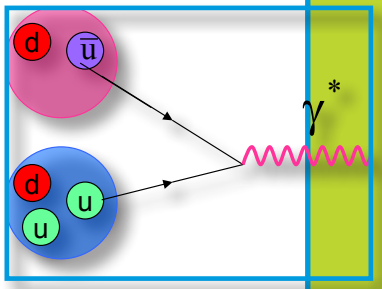
NEW

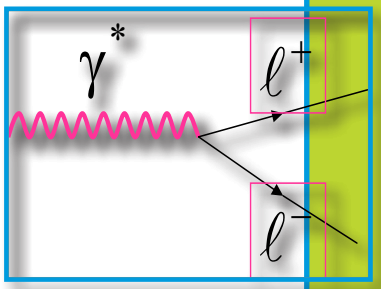
Asymmetry uncertainties	Dimuon mass (GeV/c^2) $4 < M_{\mu\mu} < 9$
$\delta A_U^{\cos 2\phi}$	0.005
$\delta A_T^{\sin \phi_S}$	0.013
$\delta A_T^{\sin(2\phi+\phi_S)}$	0.027
$\delta A_T^{\sin(2\phi-\phi_S)}$	0.027

Azimuthal asymmetries uncertainties







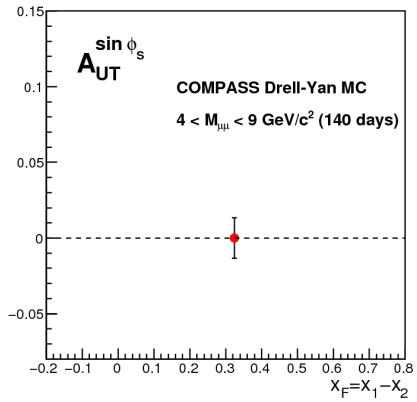


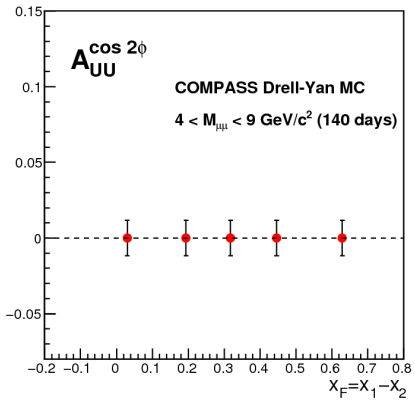
140 days of data taking
DY 4.-9. GeV/c²

Sivers

NEW

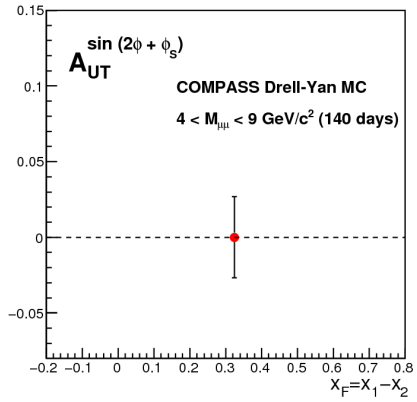
Boer - Mulders

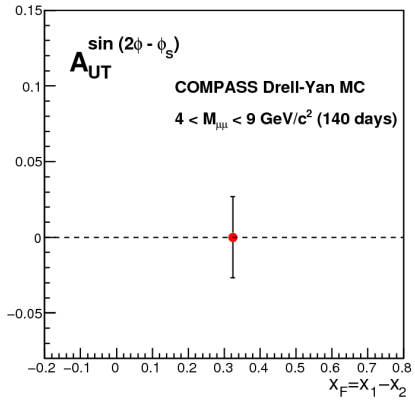




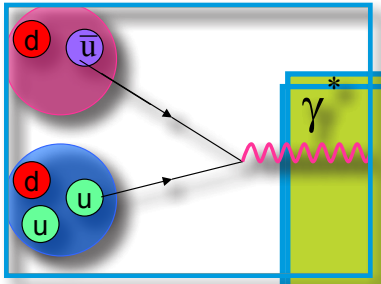
BM ⊗ pretzelosity

BM ⊗ transversity





Next-Future and Far-Future DY Plans

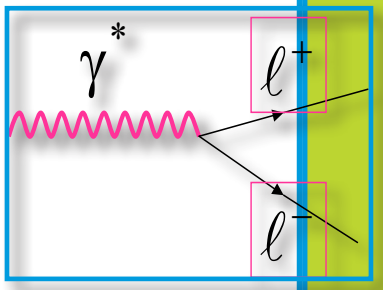


@COMPASS

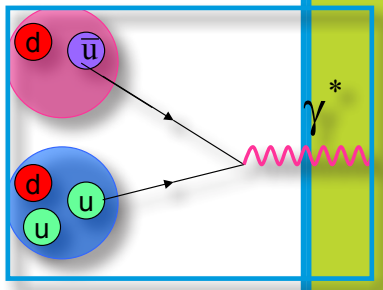
End of 2014 (un-)polarized DY pilot run on NH_3 target

2015 (un-)polarized DY run on NH_3 target +
in parallel, unpolarized DY data on thin nuclear target to study the EMC effect + kaon and antiproton induced DY

2016&2017 DVCS with μ^+ and μ^- beams on unpolarised protons +
in parallel unpolarised SIDIS

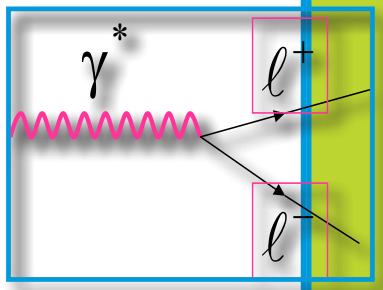


>2017 Possible second year of DY data taking - not yet approved

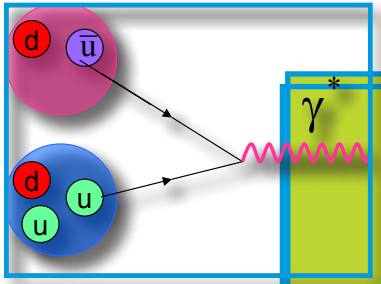


>2020 (un-)polarized Drell-Yan measurements with ^{6}LiD target

unpolarized Drell-Yan measurements with long liquid hydrogen target

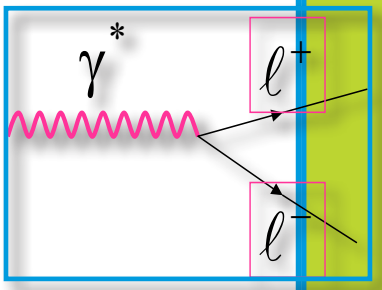


Next-Future and Far-Future DY Plans



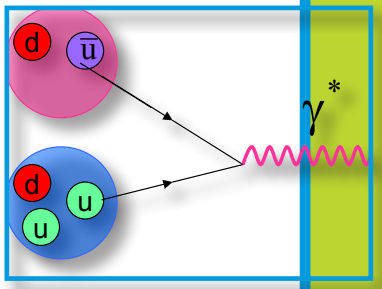
Not only COMPASS

Running Experiment E906 (SeaQuest) - Fermilab (USA)
unpolarised DY in the sea-quark region



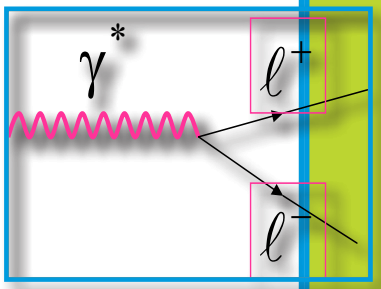
?? Polarized DY at Fermilab
Single spin asymmetry in sea quark (P_1039)
Double spin asymmetry with polarized beam (P_1027)

>2016 Star at RHIC - BNL (USA)
DY in polarized pp collisions

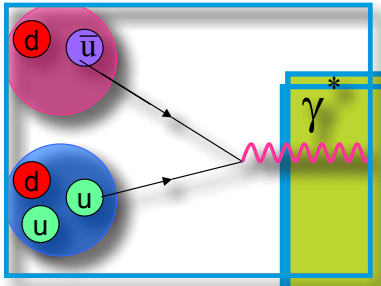


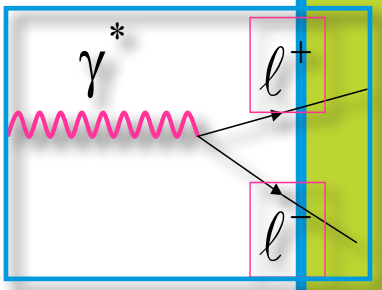
>2020 NICA Collider - JINR (Russia)
Single polarized DY measurements with proton beam

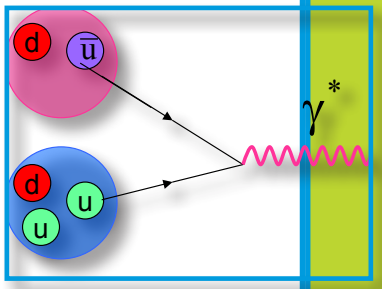
See Jen-Chieh Peng Talk (last Tuesday)

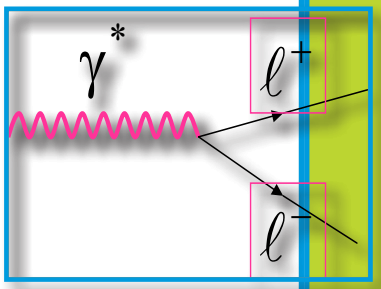


Summary





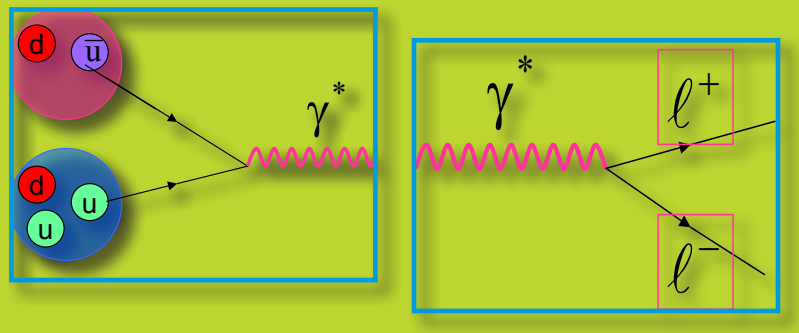




- COMPASS polarized Drell-Yan measurement will start in October 2014 with a 2 months Pilot Run.
  Physics data taking will continue during 2015 (full year)
- Second DY Run most probable in 2018
- Transversity and TMD PDFs of the nucleon are addressed in COMPASS presently from semi-inclusive DIS
- The opportunity to study, with the same spectrometer, the TMD PDFs from the Drell-Yan process is unique
- Simultaneous extraction of all relevant azimuthal asymmetries from the polarized Drell-Yan data in the mass region $4 < M_{\mu\mu} < 9$ GeV/c^2 is foreseen
- Expected statistical error in the Sivers asymmetry is <2% (with 140 days of data taking)
- In parallel, unpolarized DY data on thin nuclear target will be collected, to study the EMC effect + kaon and antiproton induced DY
- In two years of run (about 280 days) we would collect a factor of 10 larger statistics compare to any other DY experiment performed so far

COMPASS

Looking forward to contributing with a new 3D-viewer to the study of the 3D nucleon structure...

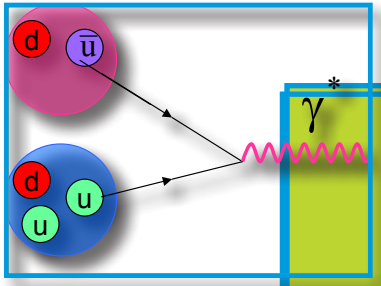


...and ready to jump into the deep

Stay tuned!!

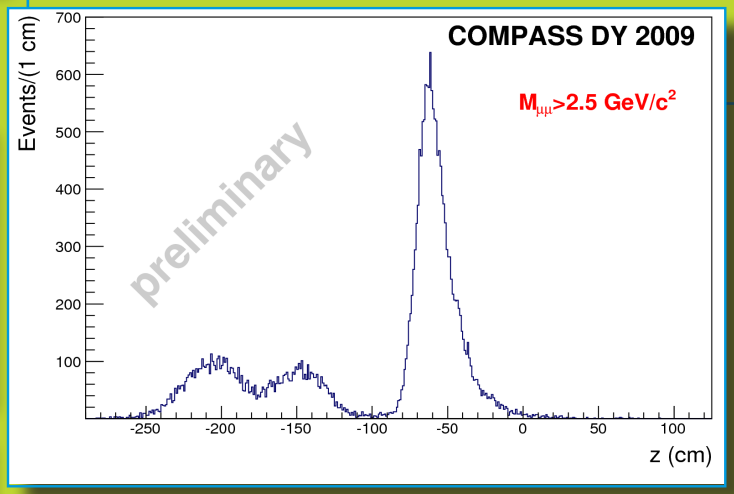
Thank you for your attention!

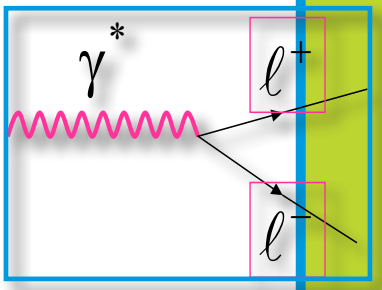
Feasibility



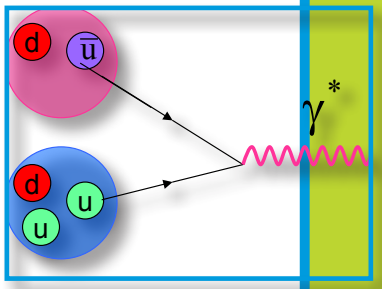
2009 3-days beam test

The vertex distribution from 2009 clearly shows the dimuon events originated in each of the target cells, as well as those produced in the tungsten beam plug.





The vertex detector will improve the resolution in vertex position reconstruction



MC simulation:
vertex detector will also improve resolution in dimuon mass reconstruction