First high p_T asymmetry for $\frac{\Delta G}{G}$ at COMPASS

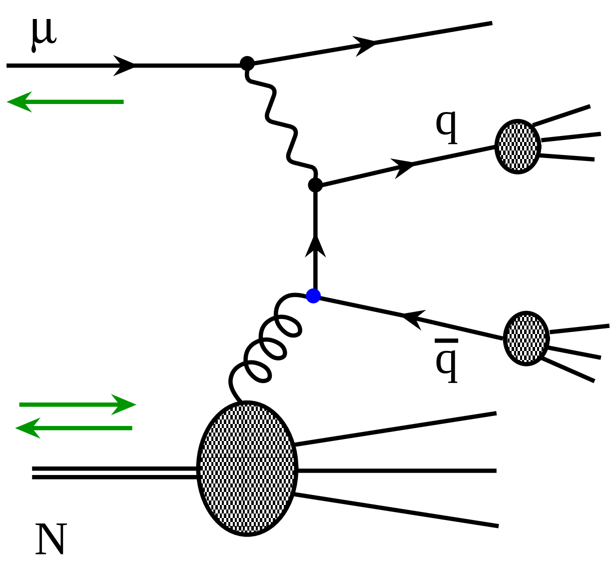
Colin Bernet, on behalf of the collaboration.

CEA/Saclay

- Measurement of the gluon polarization $\frac{\Delta G}{G}$
  - Helicity asymmetry of the photon-gluon fusion $\rightarrow \frac{\Delta G}{G}$
  - High p_T tagging $\rightarrow$ background reduction
- High p_T analysis
  - Measurement of $A_{\parallel}/D$
  - Selection of the high p_T data sample
  - False asymmetries $\rightarrow$ systematic error on $A_{\parallel}/D$
- Results

Measurement of $\frac{\Delta G}{G}$: PGF

Photon-Gluon Fusion (PGF)



Cross-section helicity asymmetry :

$$A_{pgf}^{\mu N} \equiv \frac{\Delta\sigma_{pgf}^{\mu N}}{\sigma_{pgf}^{\mu N}} \equiv \frac{\sigma_{pgf}^{\mu\uparrow N\downarrow} - \sigma_{pgf}^{\mu\uparrow N\uparrow}}{\sigma_{pgf}^{\mu\uparrow N\downarrow} + \sigma_{pgf}^{\mu\uparrow N\downarrow}}$$

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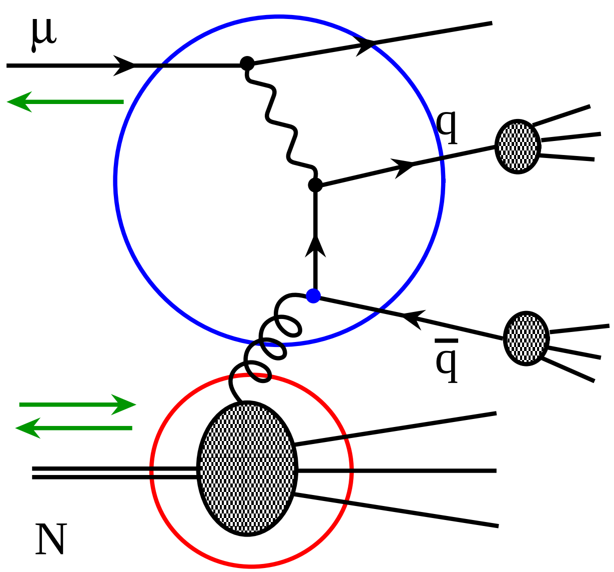

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Measurement of $\frac{\Delta G}{G}$: PGF

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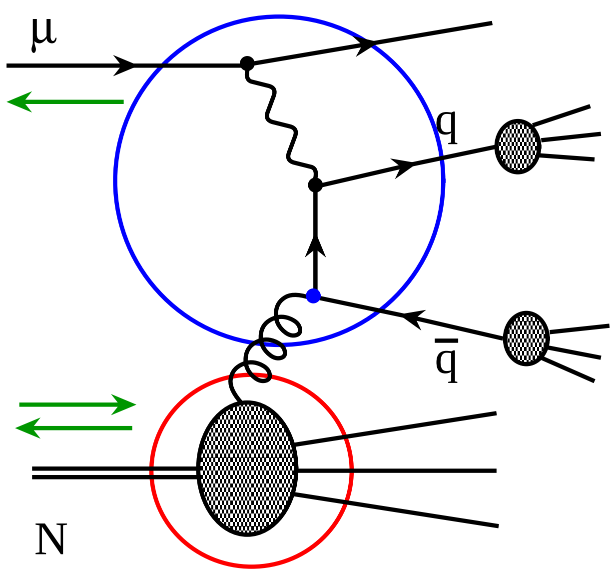

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Phase space element $(\xi, \hat{s}, ...)$:

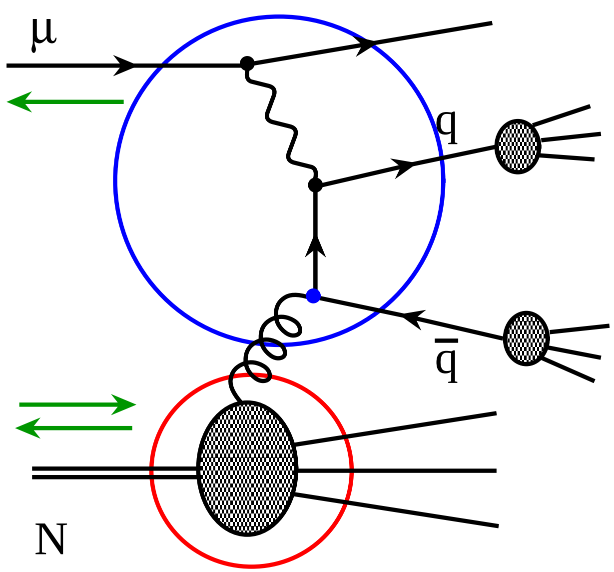
$$d\Delta\sigma^{\mu N}_{pgf} = d\Delta\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ \Delta G(\xi, \hat{s}),$$

$$d\sigma^{\mu N}_{pgf} = d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s}).$$

- $\Delta G(\xi, \hat{s})$, $G(\xi, \hat{s})$
  gluon distribution functions.
- $d\Delta\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)$, $d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)$
  differential cross-sections for the μg interaction

Measurement of $\frac{\Delta G}{G}$: PGF

Photon-Gluon Fusion (PGF)



Cross-section helicity asymmetry :

$$A^{\mu N}_{pgf} \equiv \frac{\Delta\sigma^{\mu N}_{pgf}}{\sigma^{\mu N}_{pgf}} \equiv \frac{\sigma^{\mu\uparrow N\downarrow}_{pgf} - \sigma^{\mu\uparrow N\uparrow}_{pgf}}{\sigma^{\mu\uparrow N\downarrow}_{pgf} + \sigma^{\mu\uparrow N\downarrow}_{pgf}}$$

Phase space element $(\xi, \hat{s}, ...)$:

$$\Delta\sigma^{\mu N}_{pgf} = \int d\Delta\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ \Delta G(\xi, \hat{s}),$$

$$\sigma^{\mu N}_{pgf} = \int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s}).$$

- $\Delta G(\xi, \hat{s})$, $G(\xi, \hat{s})$
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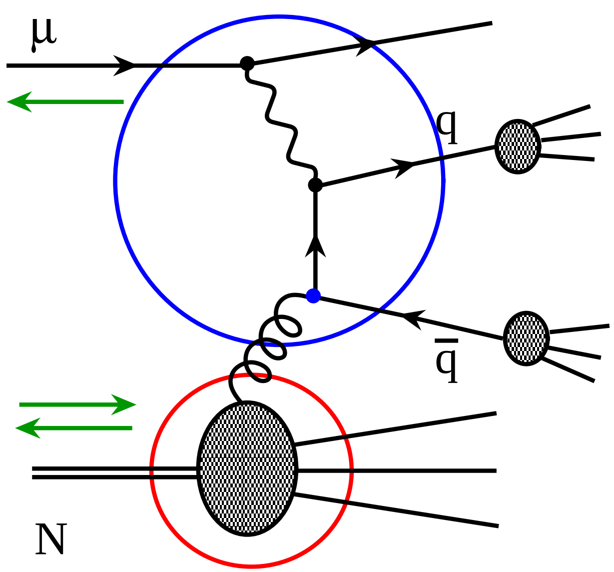
- $d\Delta\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...),\ d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)$
  differential cross-sections of the hard process.

Measurement of $\frac{\Delta G}{G}$: PGF

Photon-Gluon Fusion (PGF)



Cross-section helicity asymmetry :

$$A^{\mu N}_{pgf} = \frac{\int d\Delta\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ \Delta G(\xi, \hat{s})}{\int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s})}$$

- Analysing power :

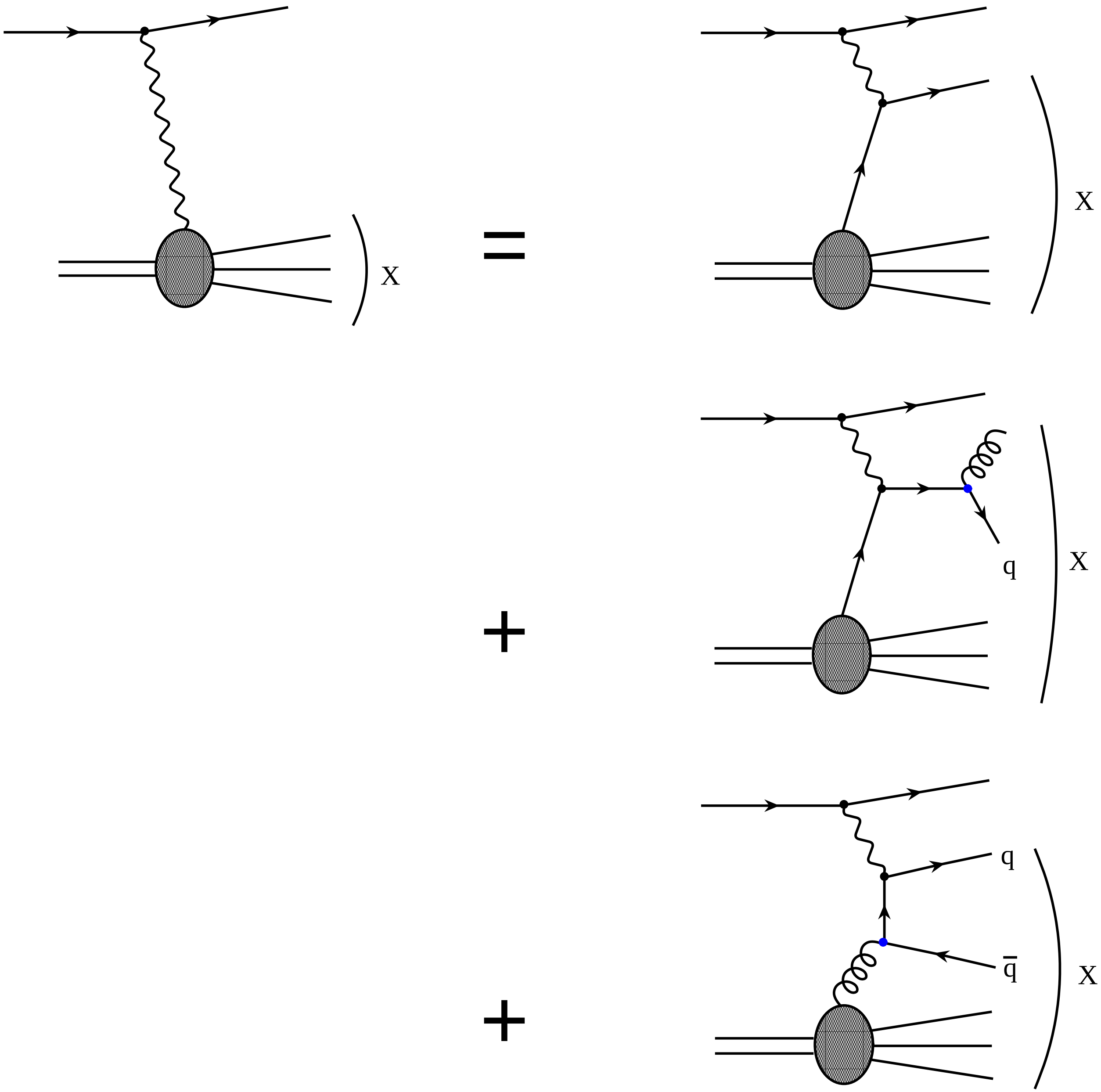
$$\hat{a}^{pgf}_{LL}(\xi, \hat{s}, ...) = \frac{d\Delta\sigma^{\mu g}_{pgf}}{d\sigma^{\mu g}_{pgf}}.$$

$$A^{\mu N}_{pgf} = \frac{\int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ \hat{a}^{pgf}_{LL}\ G(\xi, \hat{s})\ \frac{\Delta G(\xi,\hat{s})}{G(\xi,\hat{s})}}{\int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s})}$$

$$= \frac{\int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s})\ \hat{a}^{pgf}_{LL}}{\int d\sigma^{\mu g}_{pgf}(\xi, \hat{s}, ...)\ G(\xi, \hat{s})} \times \frac{\Delta G}{G}$$

$$= \langle \hat{a}^{pgf}_{LL} \rangle \frac{\Delta G}{G}$$

Measurement of $\frac{\Delta G}{G}$: High p_T cut

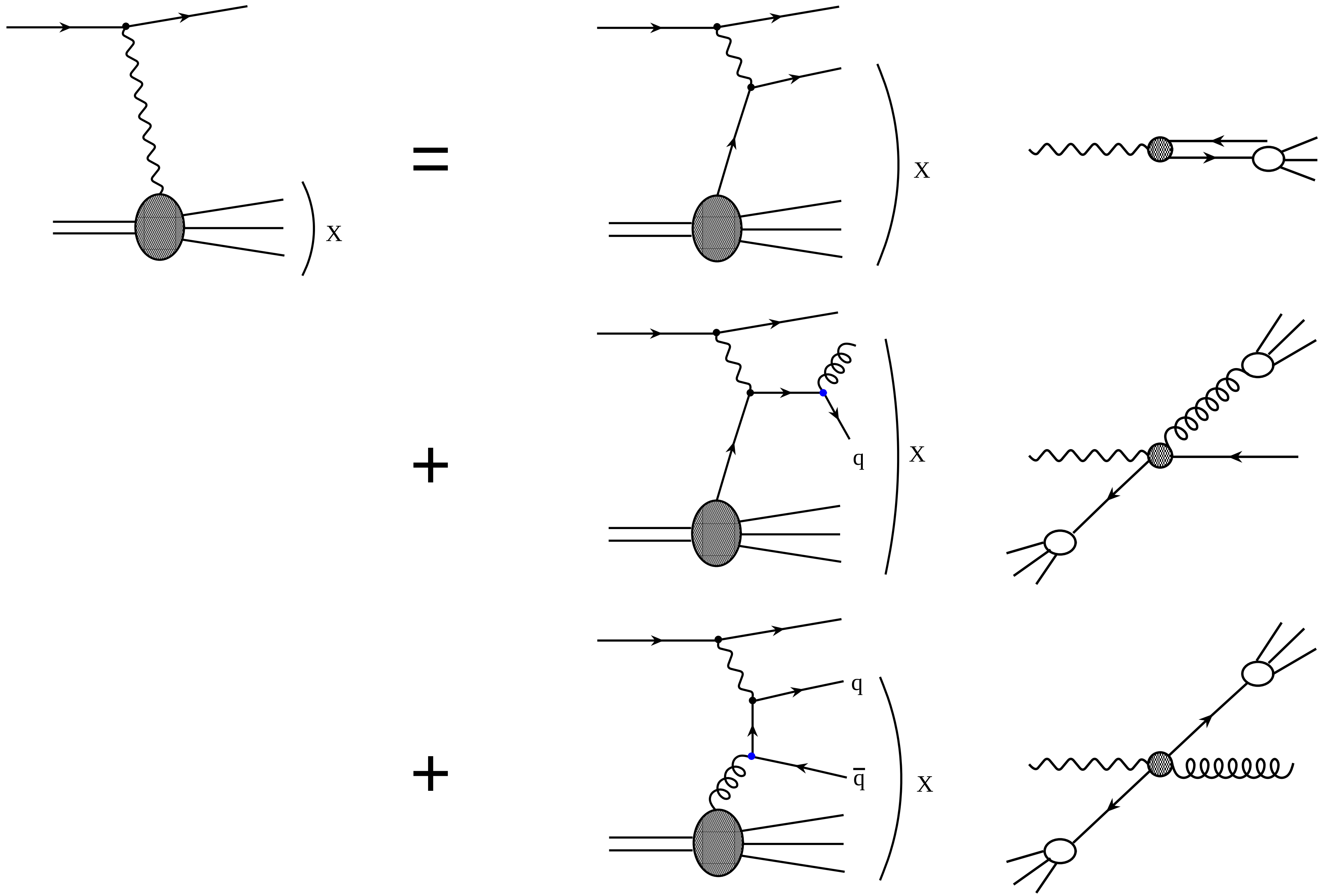


$$\sigma_{lodis} \propto \alpha$$

$$\sigma_{qcdc} \propto \alpha\alpha_s$$

$$\sigma_{pgf} \propto \alpha\alpha_s$$

Measurement of $\frac{\Delta G}{G}$: High p_T cut



Measurement of $\frac{\Delta G}{G}$: High p_T cut

The measured helicity of the total cross-section contains :

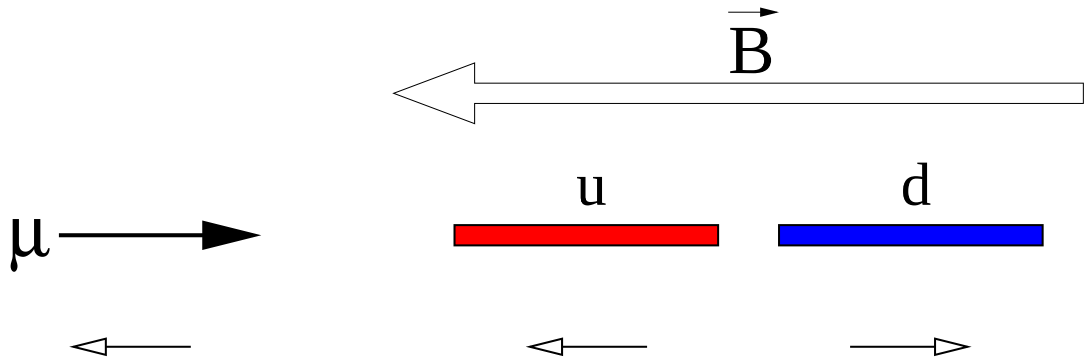
- the PGF asymmetry,
- a background asymmetry ($lodis + qcdc + ...$)

$$A_{\parallel}^{\mu d \rightarrow hh} = \frac{S}{N} \langle \hat{a}_{LL}^{pgf} \rangle \frac{\Delta G}{G} + (1 - \frac{S}{N}) A_{BG}^{\mu N}$$

- $\frac{S}{N}$ fraction of PGF events,
- $\langle \hat{a}_{LL}^{pgf} \rangle$ average analysing power,
- $A_{BG}^{\mu N}$ background asymmetry.

calculated in a Monte-Carlo simulation

Asymmetry measurement



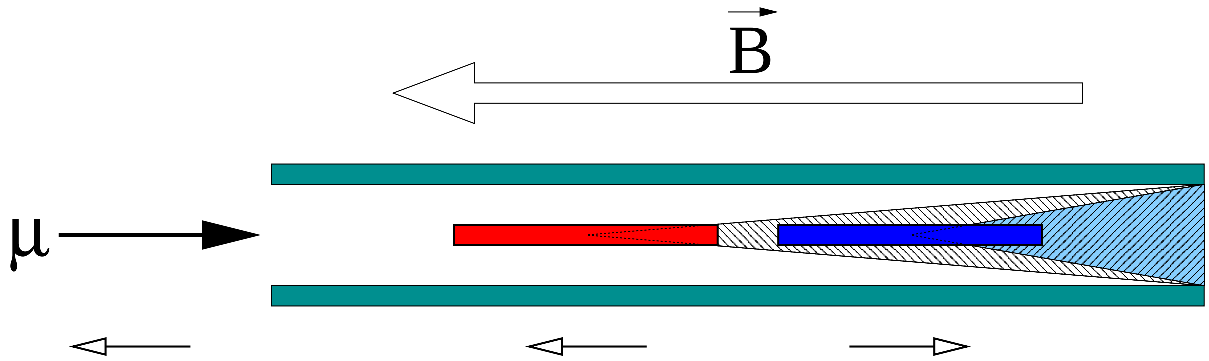
Raw counting rate asymmetry :

$$A_{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = -\frac{N_u - N_d}{N_u + N_d}$$

$$= \langle P_t P_b f D \rangle \frac{A_{\parallel}^{\mu d \to hh}}{D}$$

- P_t target polarization
- P_b beam polarization
- f dilution factor of the target
- D depolarization factor of the photon

Asymmetry measurement



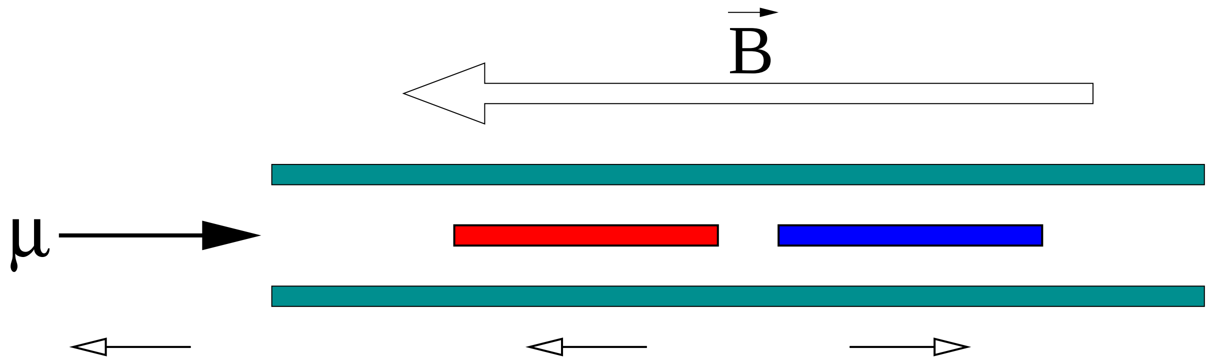
Raw counting rate asymmetry :

$$A_{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = -\frac{N_u - N_d}{N_u + N_d}$$

$$= \langle P_t P_b f D \rangle \frac{A_{\parallel}^{\mu d \rightarrow hh}}{D}$$

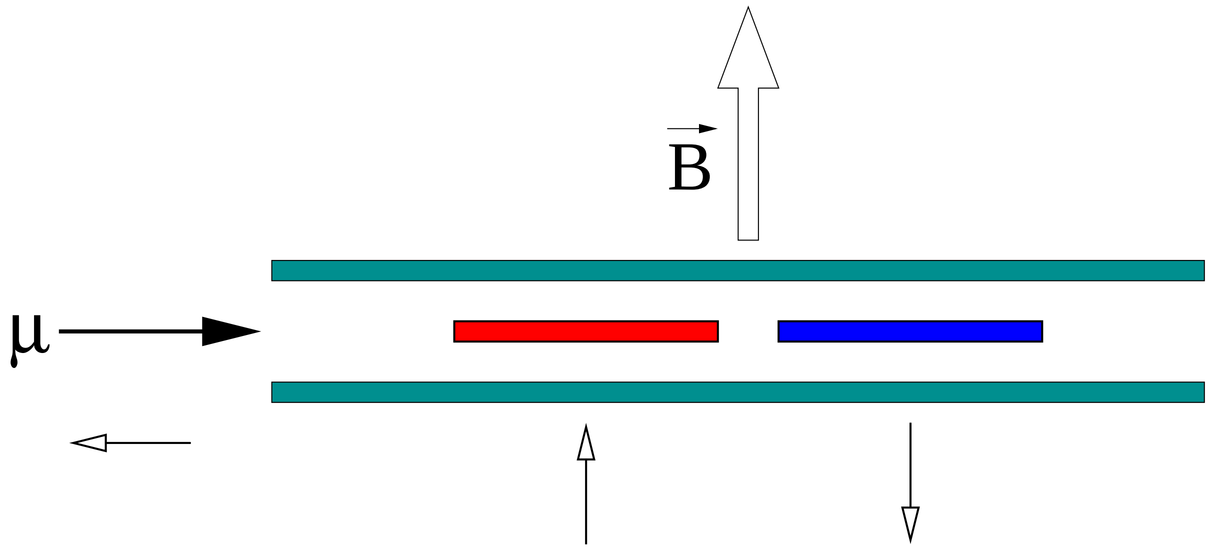
Acceptance asymmetry $\Rightarrow$ bias.

Asymmetry measurement



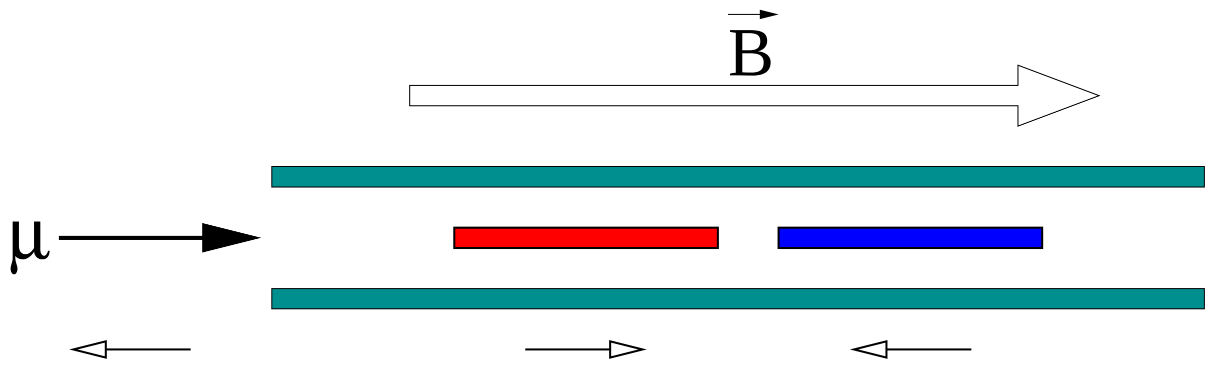
- 8 hours of data taking

Asymmetry measurement



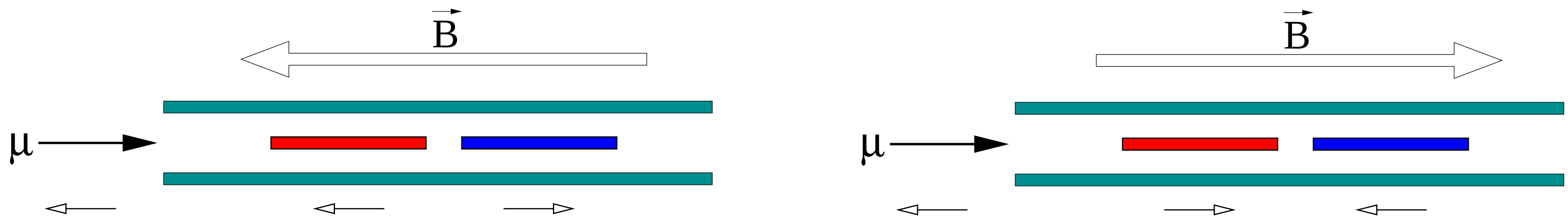
- 8 hours of data taking
- field rotation
  - adiabatic
  - ~ 20 minutes

Asymmetry measurement



- 8 hours of data taking
- field rotation
  - adiabatic
  - ~ 20 minutes
- 8 hours of data taking

Asymmetry measurement

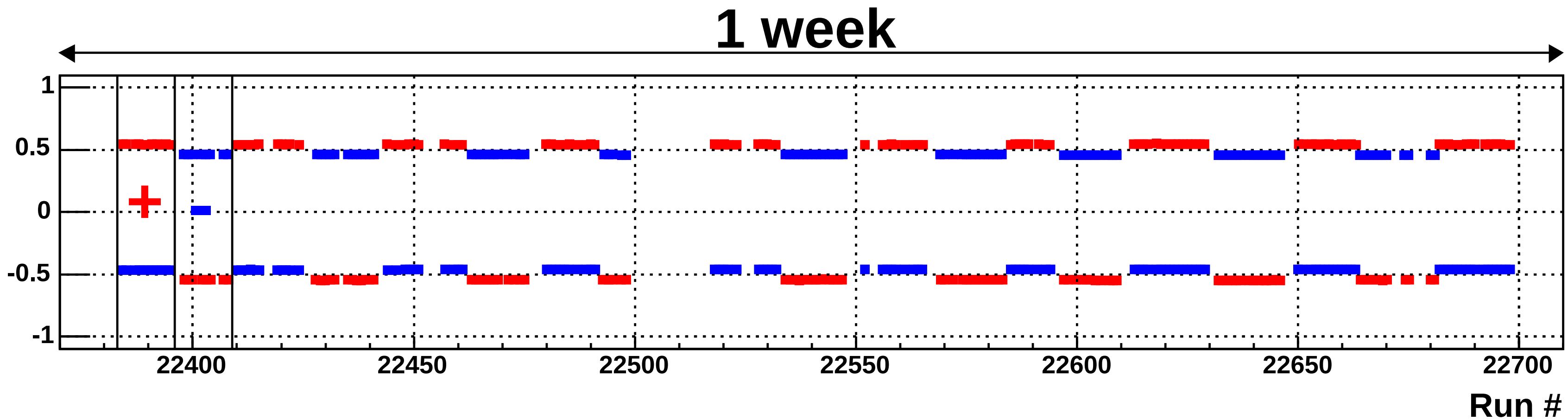


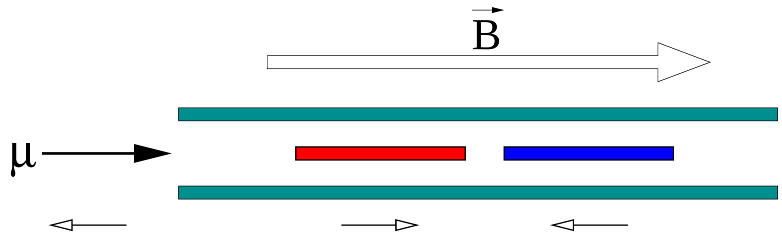
$$A_{raw} = -\frac{1}{2}\left(\frac{N_u - N_d}{N_u + N_d} - \frac{N'_u - N'_d}{N'_u + N'_d}\right)$$
$$= \langle P_t P_b f D\rangle \frac{A_{\parallel}^{\mu d \rightarrow hh}}{D}$$

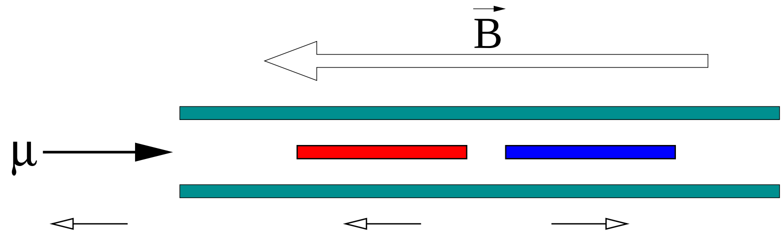
This equation

- averages $\frac{A_{\parallel}}{D}$
- cancels the acceptance asymmetry.

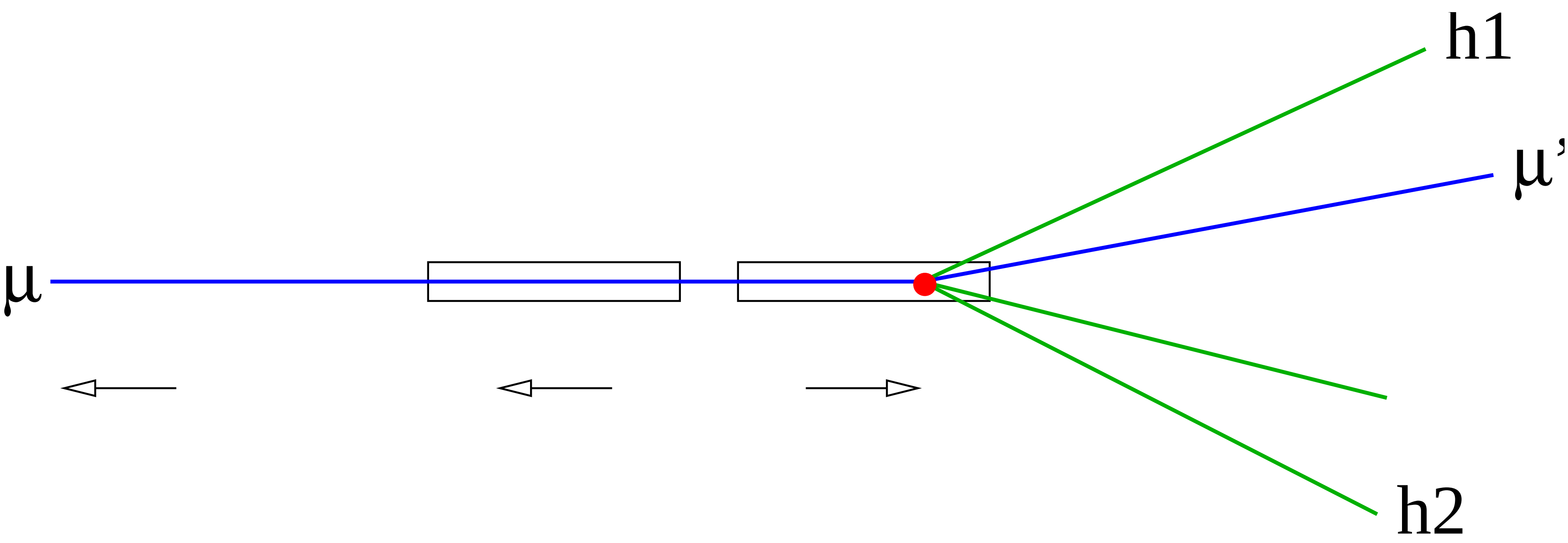
Asymmetry measurement







Event Selection

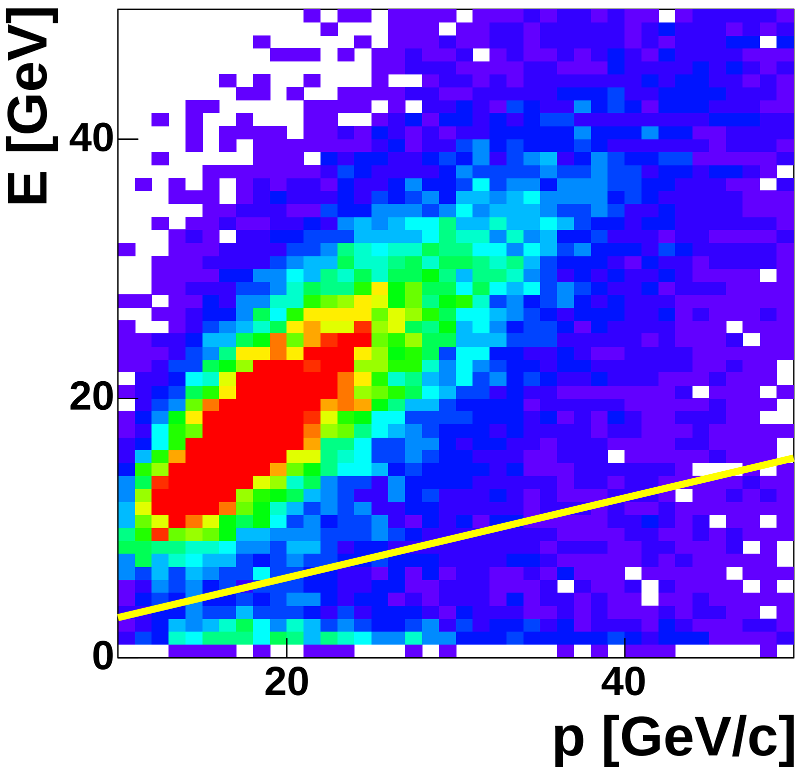


The primary vertex contains

- μ, μ' (identified by hits behind the absorber),
- at least 2 hadron candidates.

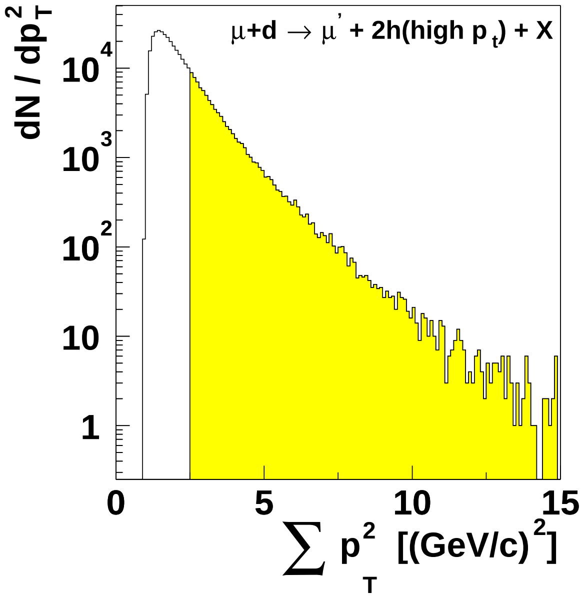
It is located in one of the target cells.

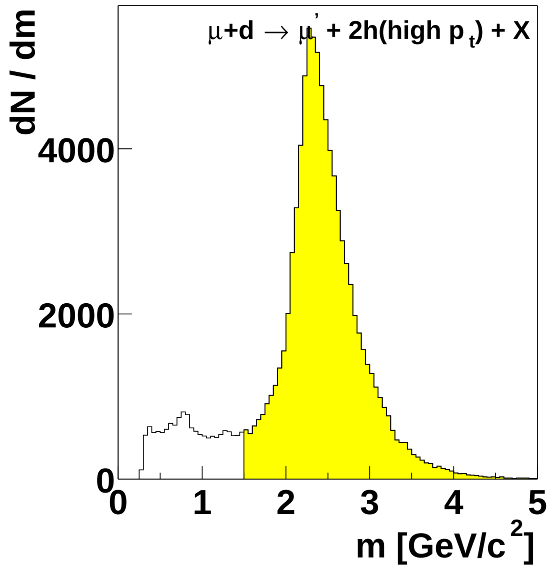
Event Selection - hadron ID



muons are removed by requiring $E_{cal}/p > 0.3$.

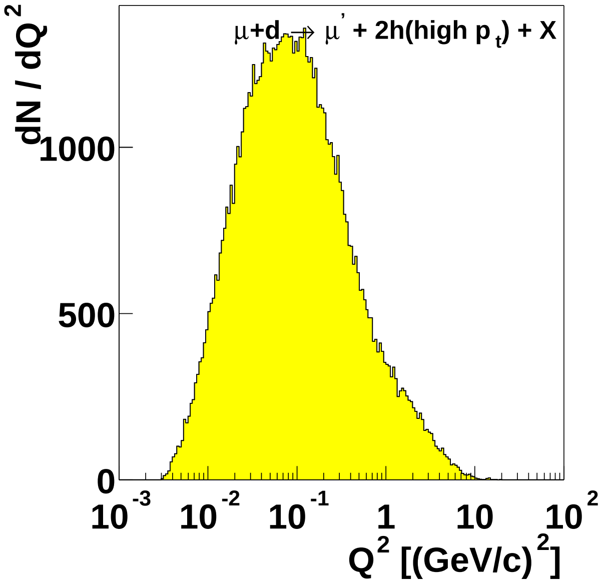
Event Selection - hadrons cuts

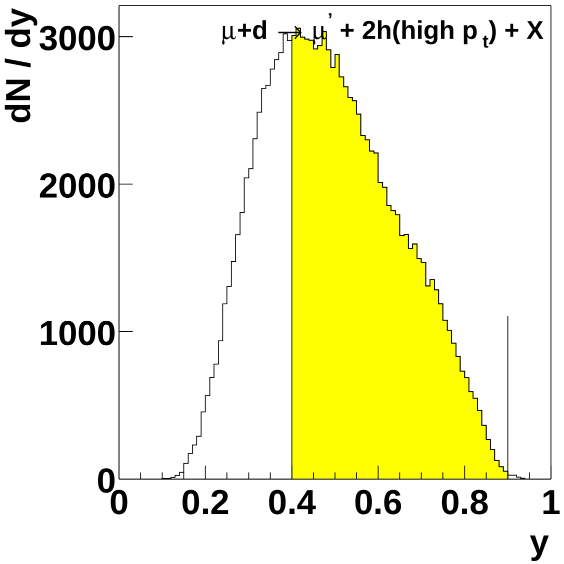




- High p_T cut
  - $p_{T1}, p_{T2} > 0.7$ GeV/c
  - $p_{T1}^2 + p_{T2}^2 > 2.5$ GeV^2/c^2
- Vector mesons are removed
  - $m(h_1 h_2) > 1.5$ GeV/c^2
- Products of the target fragmentation are removed
  - $x_F > 0.1$
  - $z > 0.1$

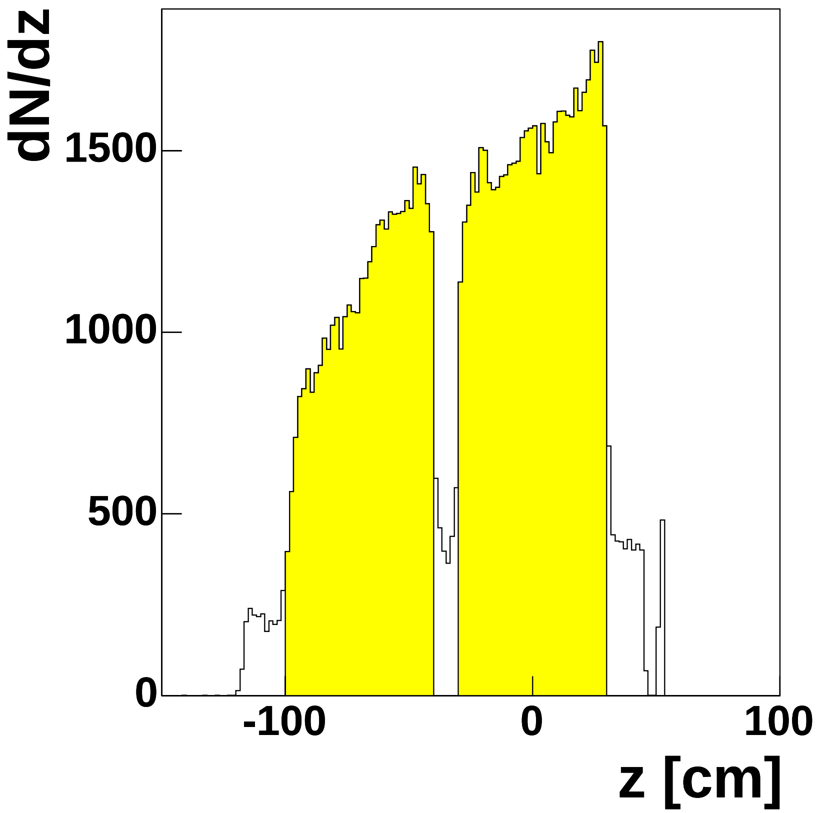
Event Selection - inclusive cuts

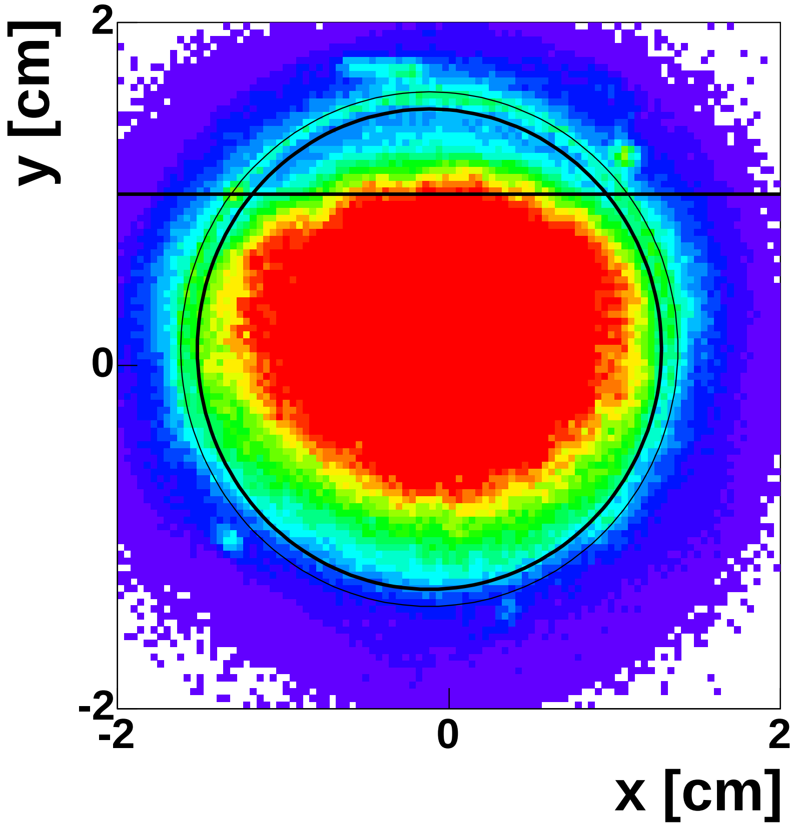




- Factorisation ensured by the high p_T cut
  - no Q^2 cut.
- Low D events removed
  - $y > 0.4$
- Events strongly affected by radiative effects removed
  - $y < 0.9$

Event Selection - target cuts





muons are required to cross both target cells

$$\Rightarrow \phi_u = \phi_d$$

False asymmetries - definition

$$\frac{A_\parallel}{D} = -\frac{1}{2\langle P_t P_b f D\rangle}\left(\frac{N_u - N_d}{N_u + N_d} - \frac{N'_u - N'_d}{N'_u + N'_d}\right)$$

- The acceptance asymmetry cancels only if :

$$\left(\frac{a_u \mathcal{L}_u}{a_d \mathcal{L}_d}\right) = \left(\frac{a_u \mathcal{L}_u}{a_d \mathcal{L}_d}\right)',$$

  - $\mathcal{L} = \phi\, n$
  - μ crosses both target cells $\Rightarrow \phi_u = \phi_d$.

$$\left(\frac{a_u n_u}{a_d n_d}\right) = \left(\frac{a_u n_u}{a_d n_d}\right)'.$$

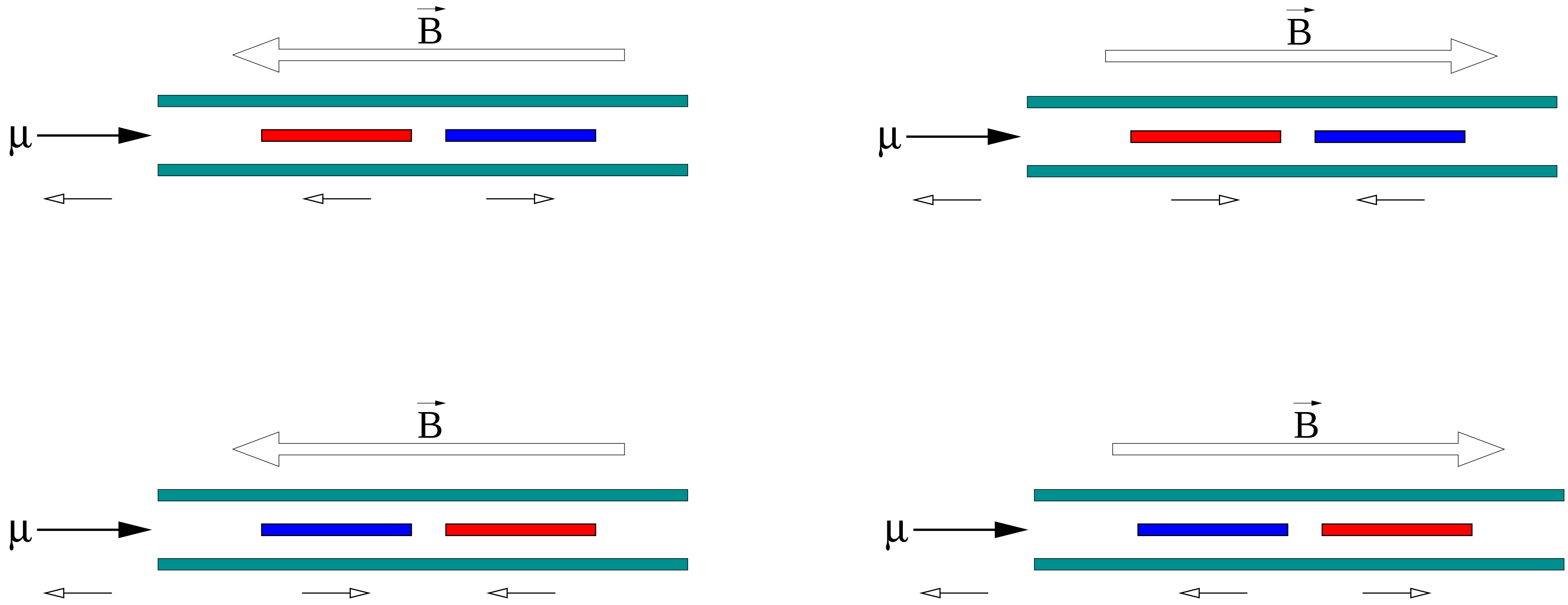
- If a_u/a_d or n_u/n_d varies during the field rotation : false asymmetries
  - *"correlated"* $\Rightarrow$ bias.
  - *"random"* $\Rightarrow$ increase of statistical error.
  - any variation $=$ "correlated" $+$ "random"

False asymmetries - correlated

$$A_+ = -\frac{1}{2\langle P_t P_b f D\rangle}\left(\frac{N_u - N_d}{N_u + N_d} - \frac{N'_u - N'_d}{N'_u + N'_d}\right) = \left(\frac{A_\parallel}{D}\right)^{\mu d \to hh} + A_{cor}$$

False asymmetries - correlated

$$A_+ = -\frac{1}{2\langle P_t P_b f D\rangle}\left(\frac{N_u - N_d}{N_u + N_d} - \frac{N'_u - N'_d}{N'_u + N'_d}\right) = \left(\frac{A_\parallel}{D}\right)^{\mu d\to hh} + A_{cor}$$



False asymmetries - correlated

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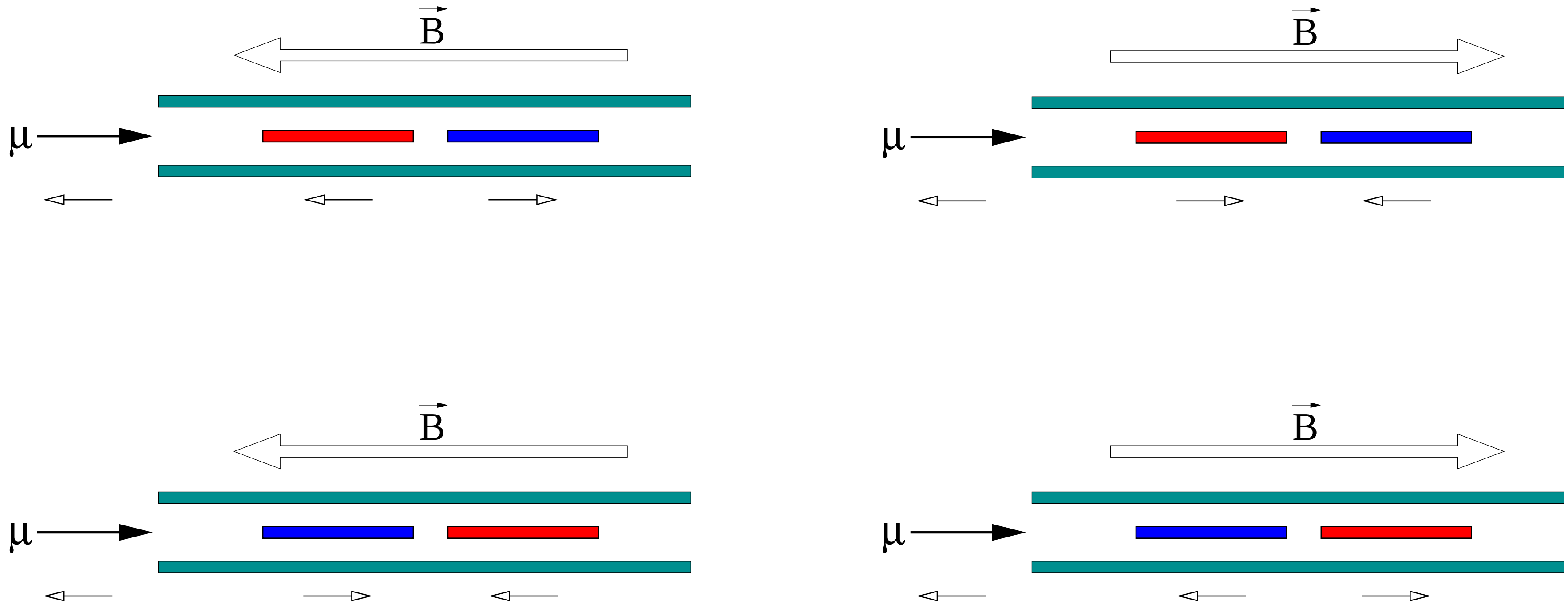


$$A_- = +\frac{1}{2\langle P_t P_b f D\rangle}\left(\frac{N_u - N_d}{N_u + N_d} - \frac{N'_u - N'_d}{N'_u + N'_d}\right) = \left(\frac{A_\parallel}{D}\right)^{\mu d \rightarrow hh} - A_{cor}$$

False asymmetries - correlated

Periods	Microwave setup	Measured asymmetry
$P2D$, $P2E$, $P2F$, $P2G+$	$+$	$A_+ = \frac{A_\parallel}{D} + A_{cor}$
$P2A2$, $P2G-$	$-$	$A_- = \frac{A_\parallel}{D} - A_{cor}$

- If we measure A_+ and A_- :

$$\frac{A_\parallel}{D} = \frac{1}{2}(A_+ + A_-),$$
$$A_{cor} = \frac{1}{2}(A_+ - A_-).$$

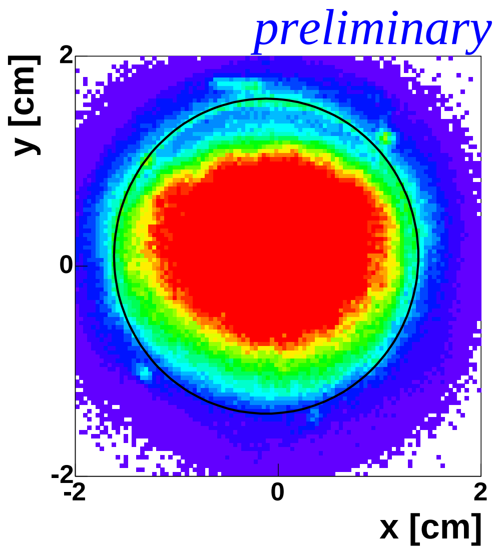
- A_{cor} cancels in the arithmetic average of A_+ and A_-.
  but we do a weighted average $\Rightarrow A_{cor}$ cancels partially.
- A_{cor} must be measured.
  remaining fraction $\rightarrow$ systematic error on $\frac{A_\parallel}{D}$.

False asymmetries - low p_T sample

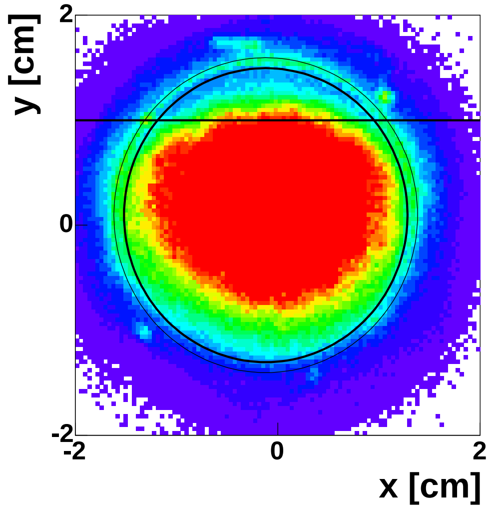
- high p_T sample $\rightarrow$ no A_{cor} observed.
  $\Rightarrow A_{cor}$ is smaller than the statistical error. This does not mean that it is negligible.
- definition of the low p_T sample :
  - $p_T^2 < 0.5$ (GeV/c)^2,
  - no cut on $m(h_1 h_2)$.
  - $Q^2 < 0.5$ (GeV/c)^2,
  - no cut on x_F, nor z.
  - all other cuts as in the high p_T sample.

  $\rightarrow$ 250 times more events.

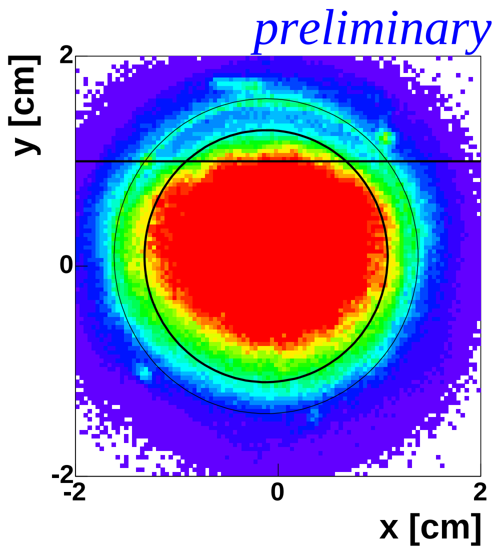
False asymmetries - low p_T sample



wide



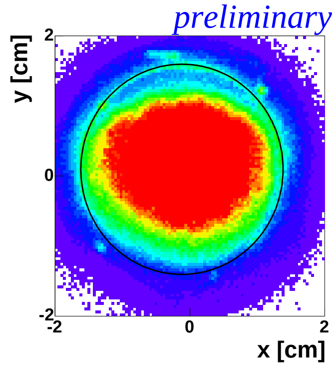
optimal

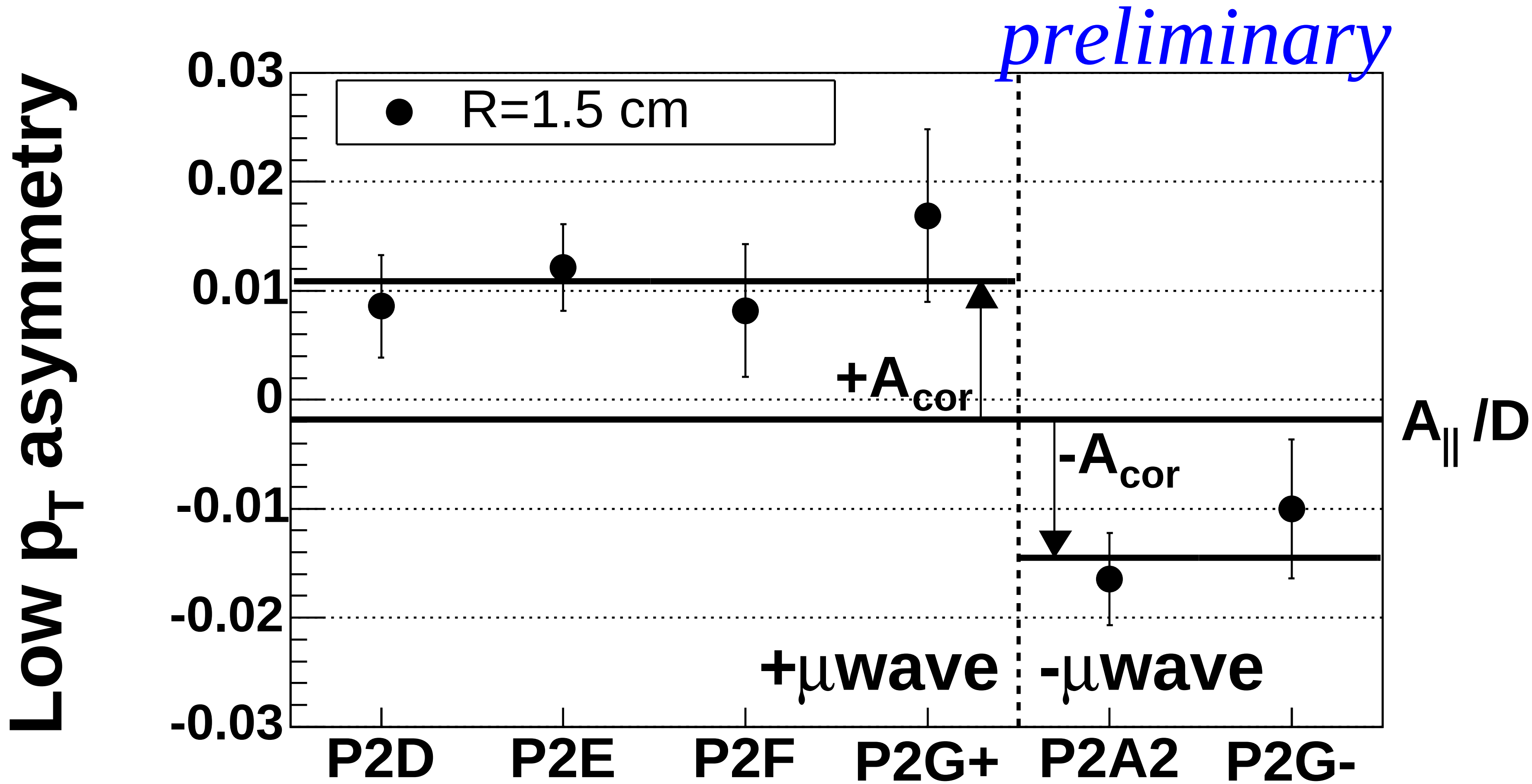


tight

False asymmetries - low p_T sample

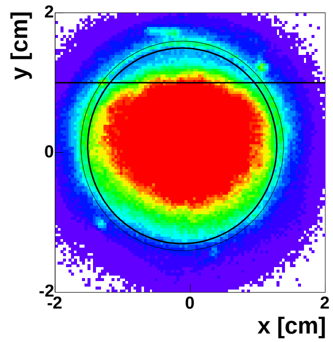
wide target cuts

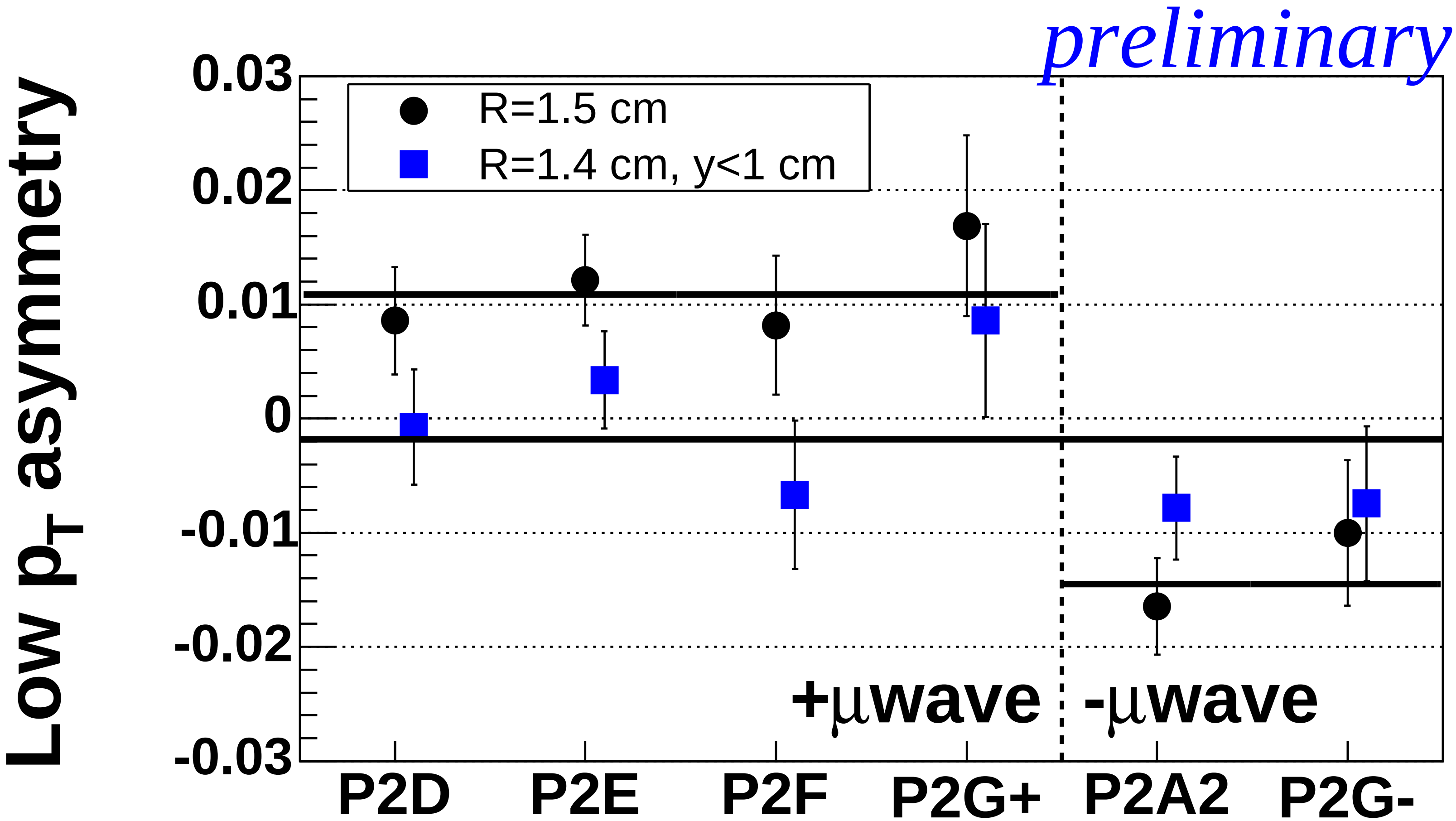




False asymmetries - low p_T sample

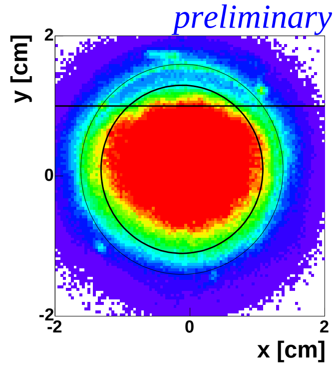
optimal target cuts

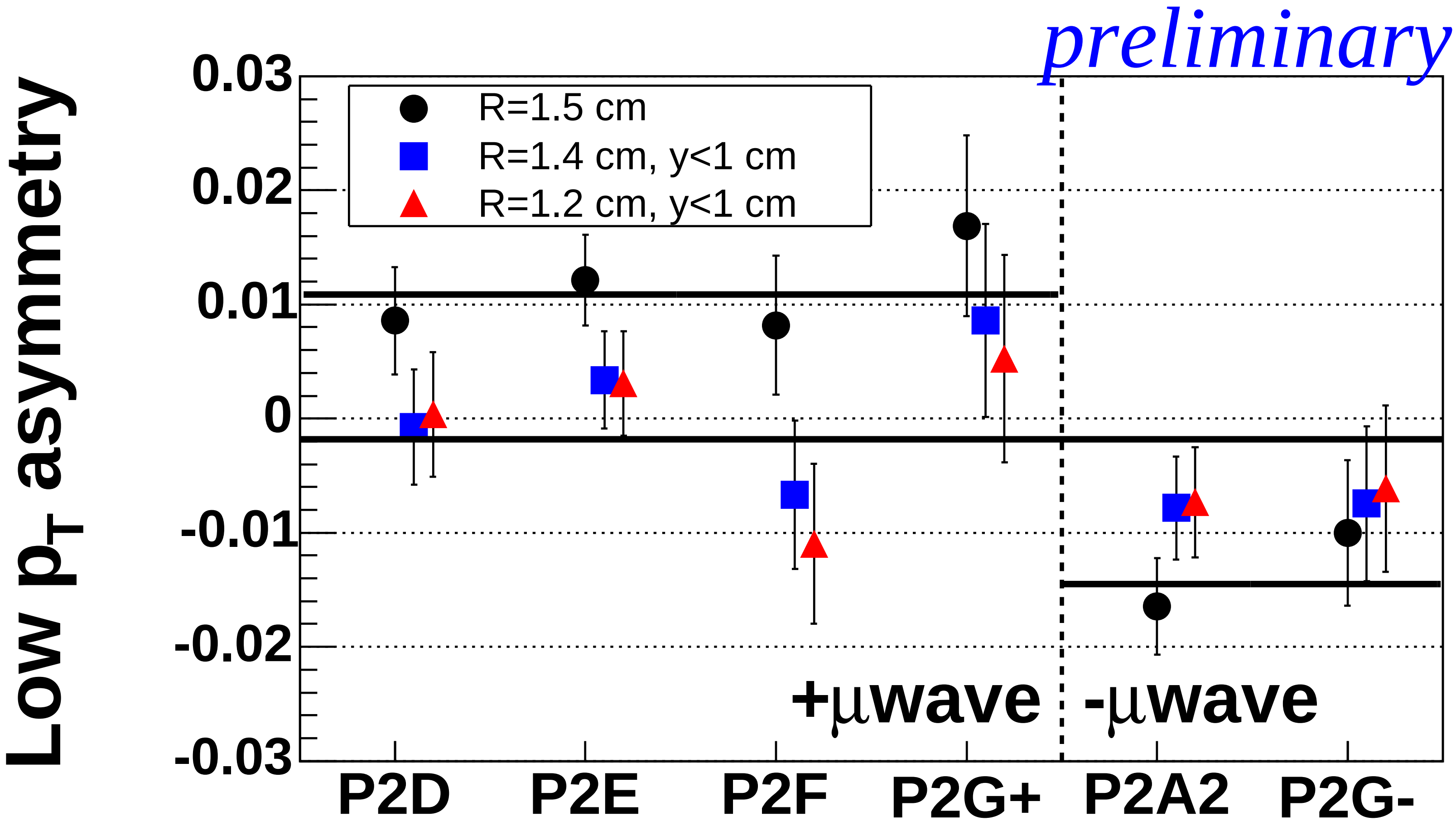




False asymmetries - low p_T sample

tight target cuts

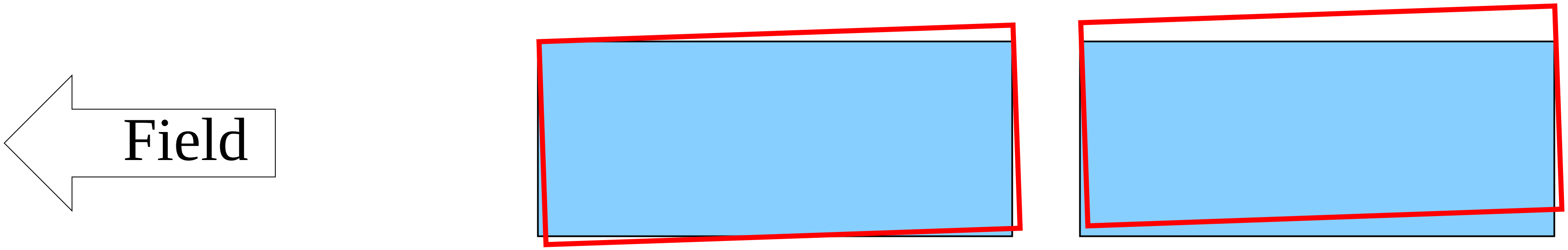




False asymmetries - low p_T sample

$$\frac{n_u}{n_d} = 1$$

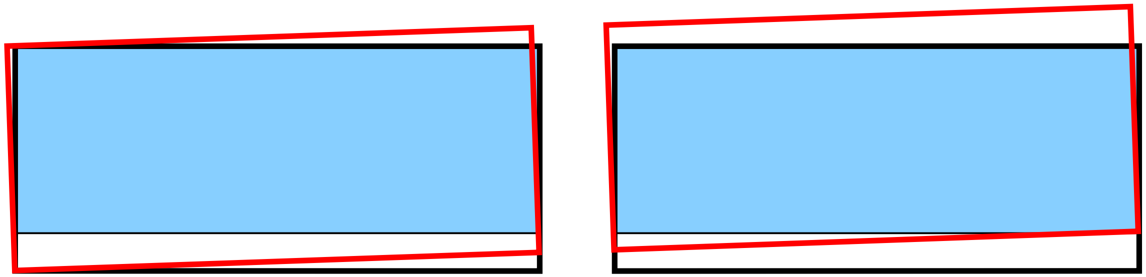
False asymmetries - low p_T sample



$$\frac{n_u}{n_d} > 1$$

- The target moves when the field is reversed
  $\leftarrow$ the field of the target solenoide tends to align on the fringe field of the spectrometer dipole.

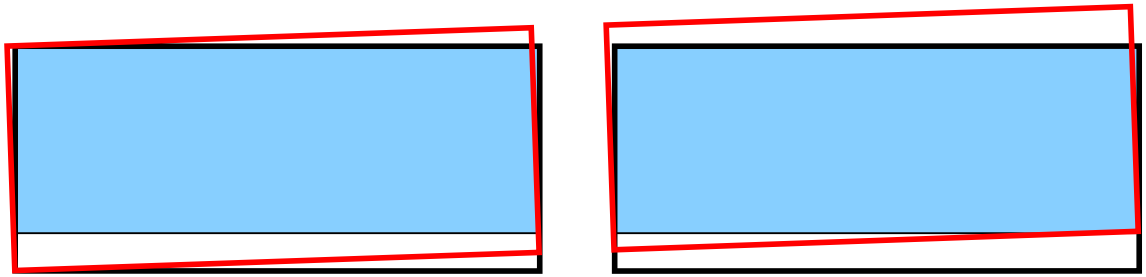
False asymmetries - low p_T sample



$$\frac{n_u}{n_d} = 1$$

- The target moves when the field is reversed
  $\leftarrow$ the field of the target solenoide tends to align on the fringe field of the spectrometer dipole.
- Tighter target cuts remove this effect.

False asymmetries - low p_T sample



$$\frac{n_u}{n_d} = 1$$

A $300\ \mu$m target movement has been measured.

- Enough to explain the false asymmetry observed with the wide cuts.
- Explains why :
  - optimal cuts are enough to remove this false asymmetry
  - tight cuts have no effect.

False asymmetries - low p_T sample

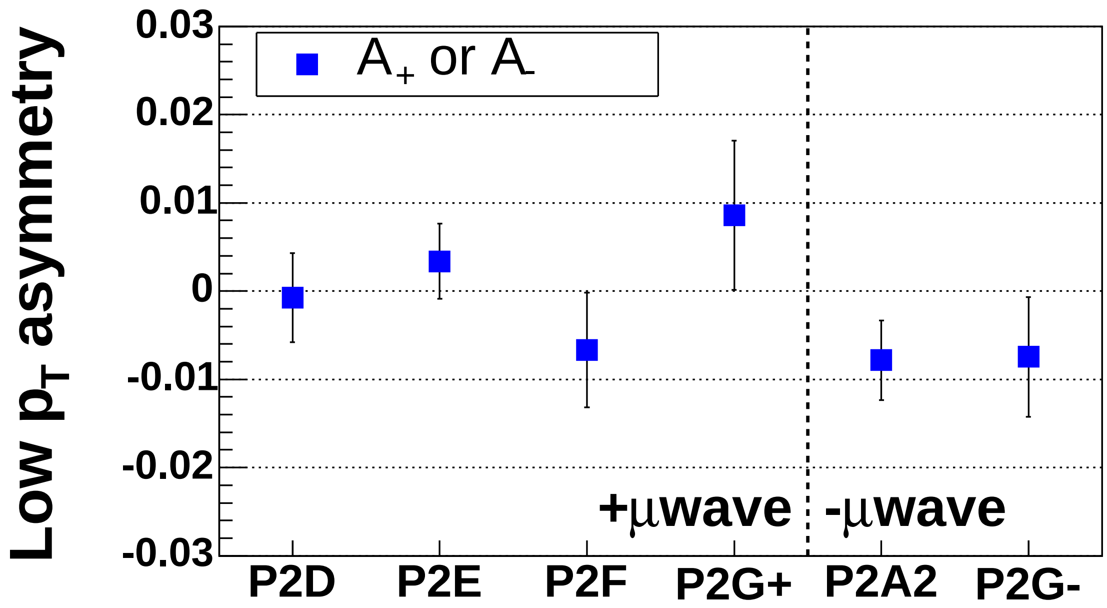
- remaining correlated false asymmetry with the optimal target cuts :

$$A_{cor} = \frac{1}{2}(A_+ - A_-) = 0.0043 \pm 0.0023.$$

- remaining correlated false asymmetry after weighted average :

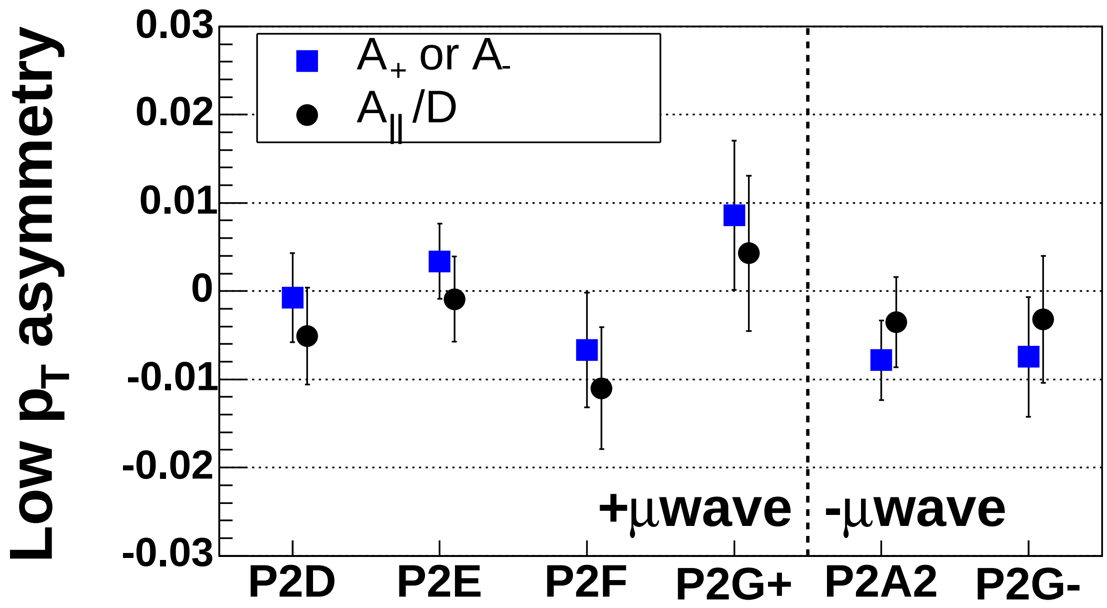
$$\boxed{A_{cor} = 0.0018 \pm 0.0010.}$$

False asymmetries - low p_T sample



- optimal target cuts

False asymmetries - low p_T sample



- $+\mu$wave : $\frac{A_\parallel}{D} = A_+ - A_{cor}$
- $-\mu$wave : $\frac{A_\parallel}{D} = A_- + A_{cor}$
- $\frac{A_\parallel}{D}$ does not depend on the μwave setup (by definition)
- the fluctuations of $\frac{A_\parallel}{D}$ are due to :
  - statistics
  - the uncorrelated false asymmetry A_{uncor}

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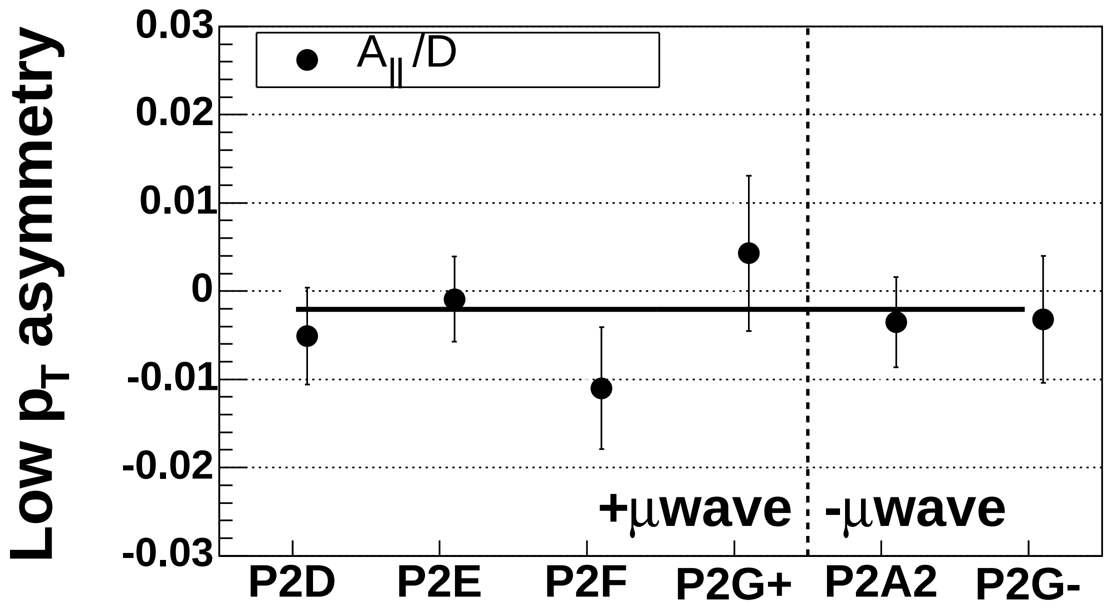

- The 6 points are compatible
  - $\chi^2/ndf = 2.35/6$
  - χ^2 probability : 88%

  $\rightarrow A_{uncor}$ is smaller than the statistical error.
- if we assume $A_{uncor} < 0.01$ for each period:

$$\boxed{A_{uncor} < 0.004.}$$

False asymmetries - conclusion

- We obtained, with the low p_T sample :

$$A_{cor} = 0.0018 \pm 0.0010.$$
$$A_{uncor} < 0.004.$$

- Studies show that these results also hold for the hight p_T sample.
- Other approaches have been followed to test false asymmetries, at high and low p_T.
  - asymmetry calculated for upper, lower Jura, Saleve part of the spectrometer.
  - asymmetry calculated between the 2 halves of a single target cell

$\rightarrow$ no problem.

We thus chose, conservatively :

$$\delta\left(\frac{A_{\parallel}}{D}\right)^{\mu d \rightarrow hh}(syst.) = 0.01$$

Conclusion

For 2002 data, the preliminary asymmetry of the total cross-section for the production of 2 high p_T hadrons is :

$$\left(\frac{A_\parallel}{D}\right)^{\mu d \to hh} = -0.065 \;\pm\; 0.036(stat.) \;\pm\; 0.01(syst.).$$

- radiative effects are not taken into account.
  (should be small for semi-inclusive DIS).
- the systematic error contains only the contribution of false asymmetries.
  (other sources should be $\propto \left(\frac{A_\parallel}{D}\right)^{\mu d \to hh}$, hence small)
- projected statistical error (including 2003 and 2004) : 0.018
- A monte-carlo simulation is under way to extract $\frac{\Delta G}{G}$ from this result.