NLO QCD predictions for gluon polarization from open-charm asymmetries measured at COMPASS

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SPIN
DUBNA
2009

- Part I - *Open-charm results on gluon polarization from COMPASS* - *on behalf of the COMPASS Collaboration*

- Part II - *NLO QCD predictions for gluon polarization from open-charm asymmetries measured at COMPASS*

COMPASS Collaboration at CERN

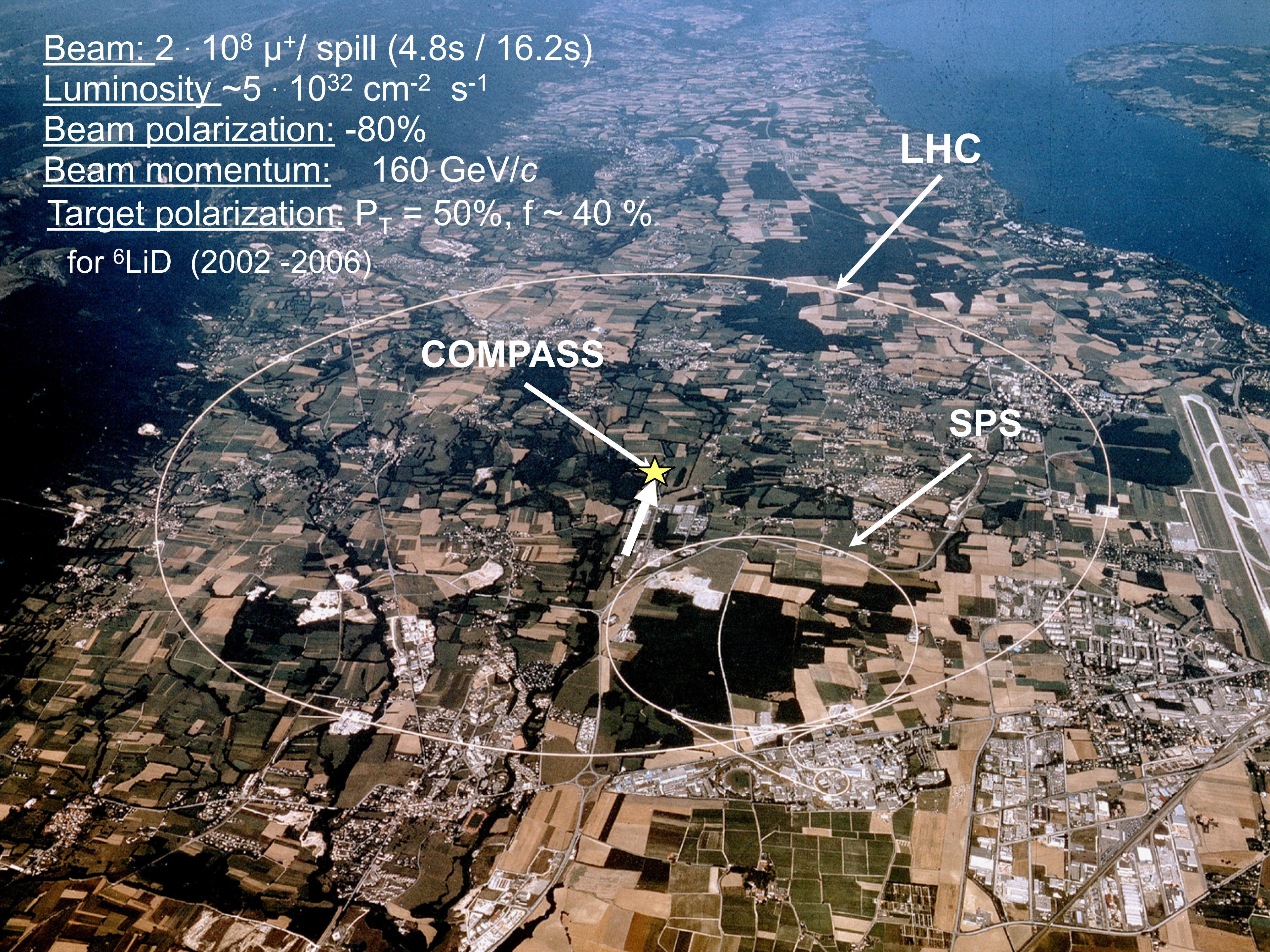
Common Muon and Proton Apparatus

for Structure and Spectroscopy

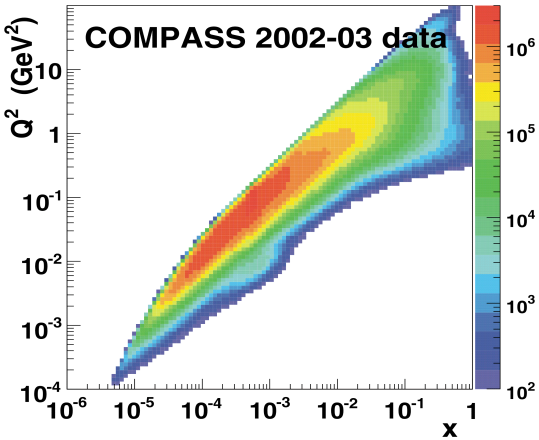
Czech Rep., France, Germany, India, Israel, Italy, Japan, Poland, Portugal, Russia and CERN

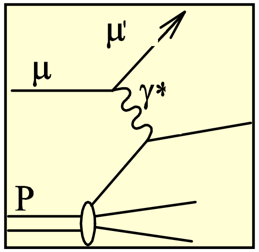
Bielefeld, Bochum, Bonn, Burdwan and Calcutta, CERN, Dubna, Erlangen, Freiburg, Lisbon, Mainz, Moscow, Munich, Prague, Protvino, Saclay, Tel Aviv, Torino, Trieste, Warsaw, Yamagata

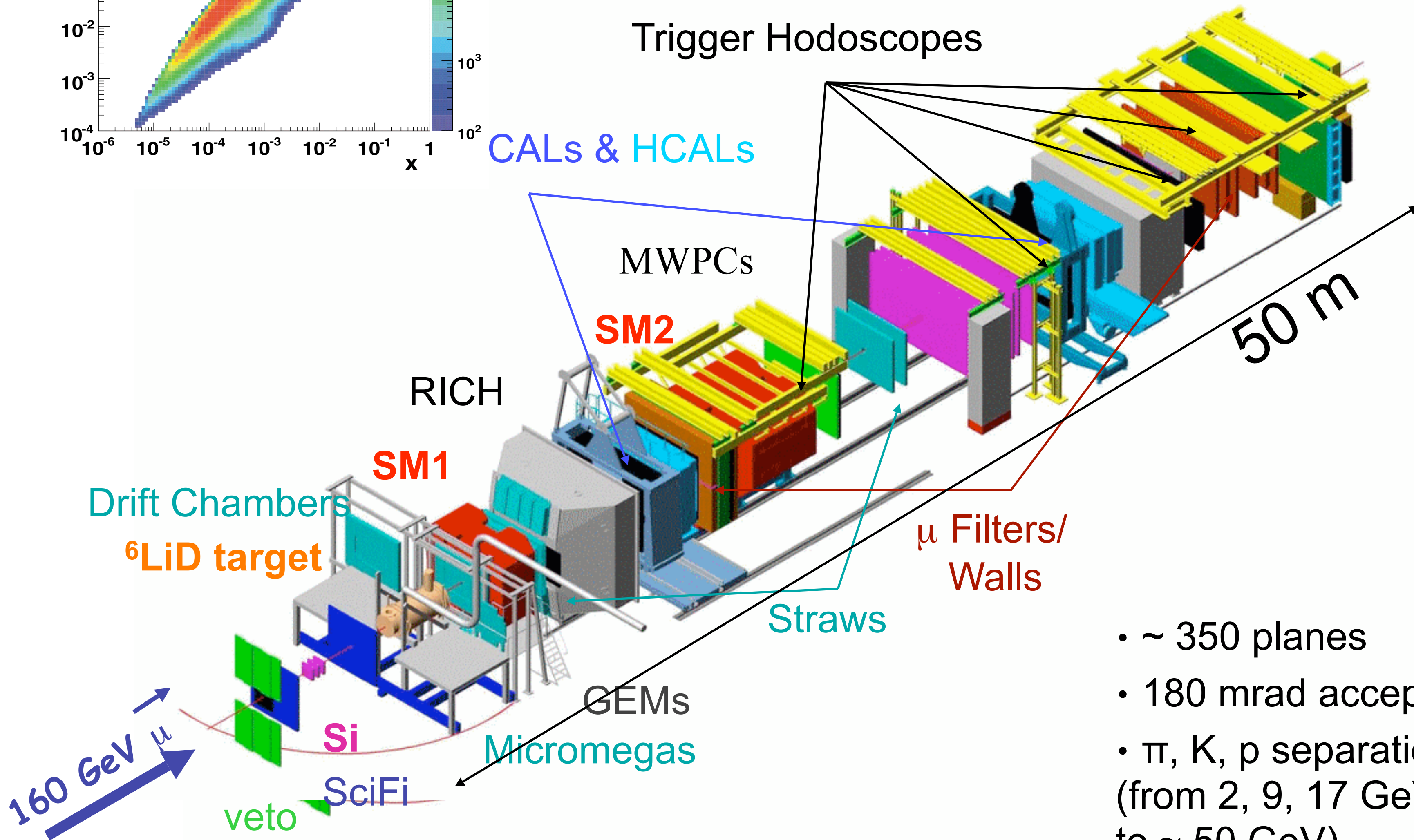
~240 physicists, 30 institutes


Beam: $2 \cdot 10^8$ μ^+/ spill (4.8s / 16.2s)
Luminosity ~$5 \cdot 10^{32}$ cm^{-2} s^{-1}
Beam polarization: -80%
Beam momentum: 160 GeV/c
Target polarization: P_T = 50%, f ~ 40 %
for ^{6}LiD (2002 -2006)
LHC
COMPASS
SPS

COMPASS in muon run
NIM A 577(2007) 455

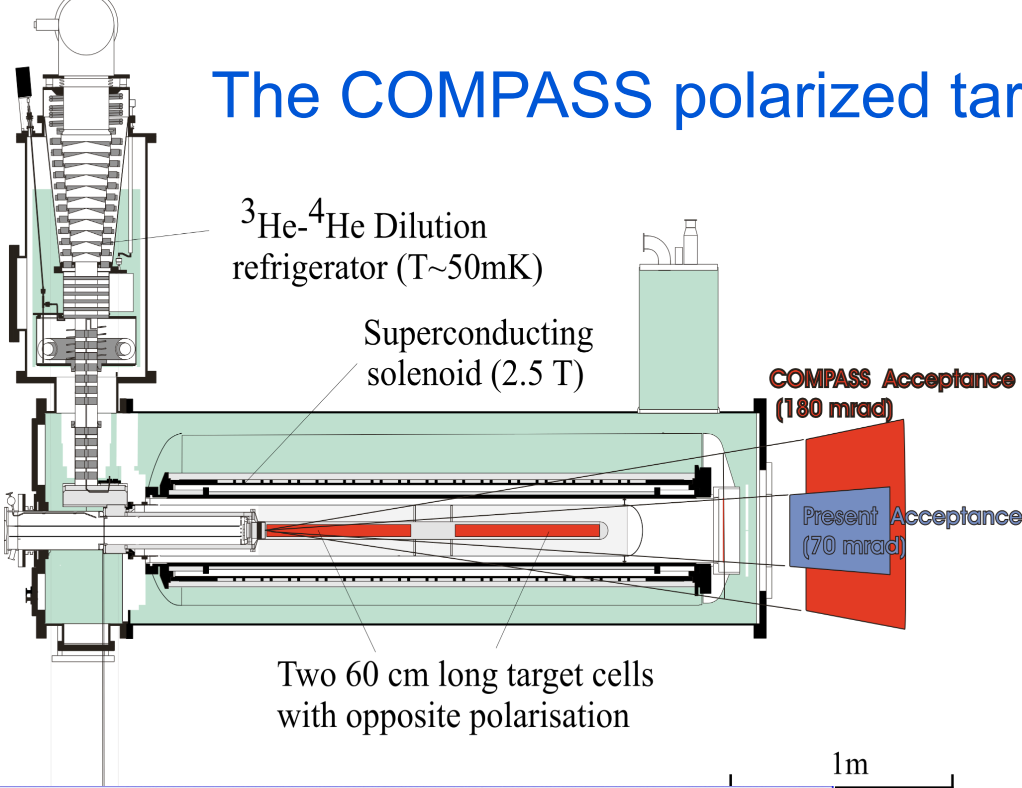






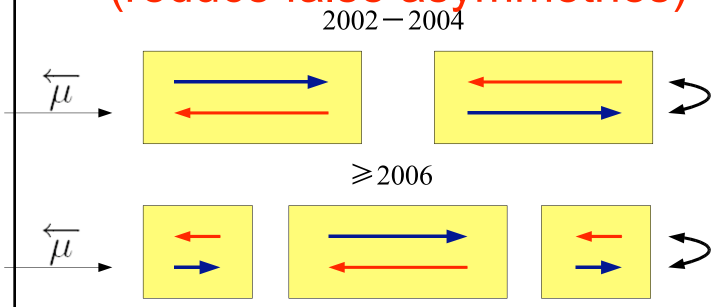
- ~ 350 planes
- 180 mrad acceptance
- π, K, p separation (from 2, 9, 17 GeV up to ~ 50 GeV)

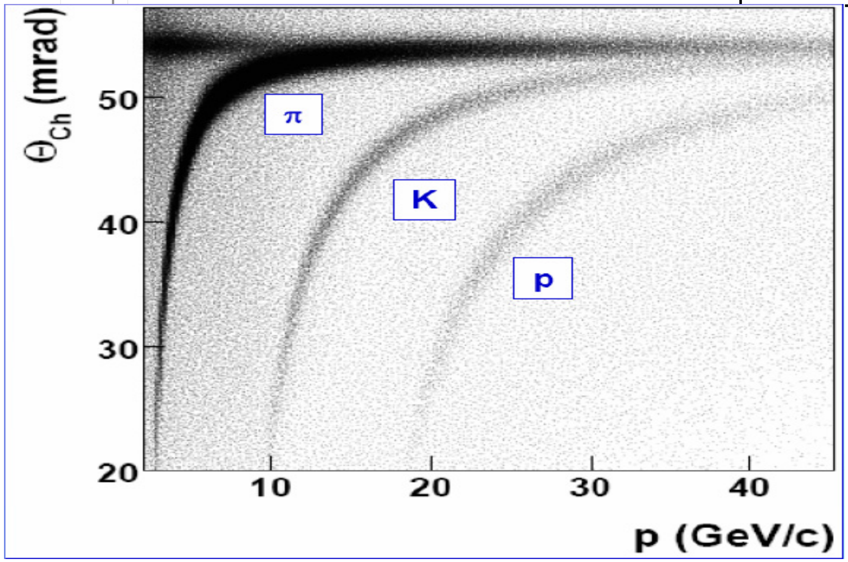
The COMPASS polarized target



Target material: ^{6}LiD
Polarisation: >50%
Dilution factor: ~0.4
Dynamic Nuclear Polarization

2006 - new solenoid
with acceptance 180 mrad
3 target cells
(reduce false asymmetries)





RICH 2006 upgrade : better PID

MAPMTs in central region

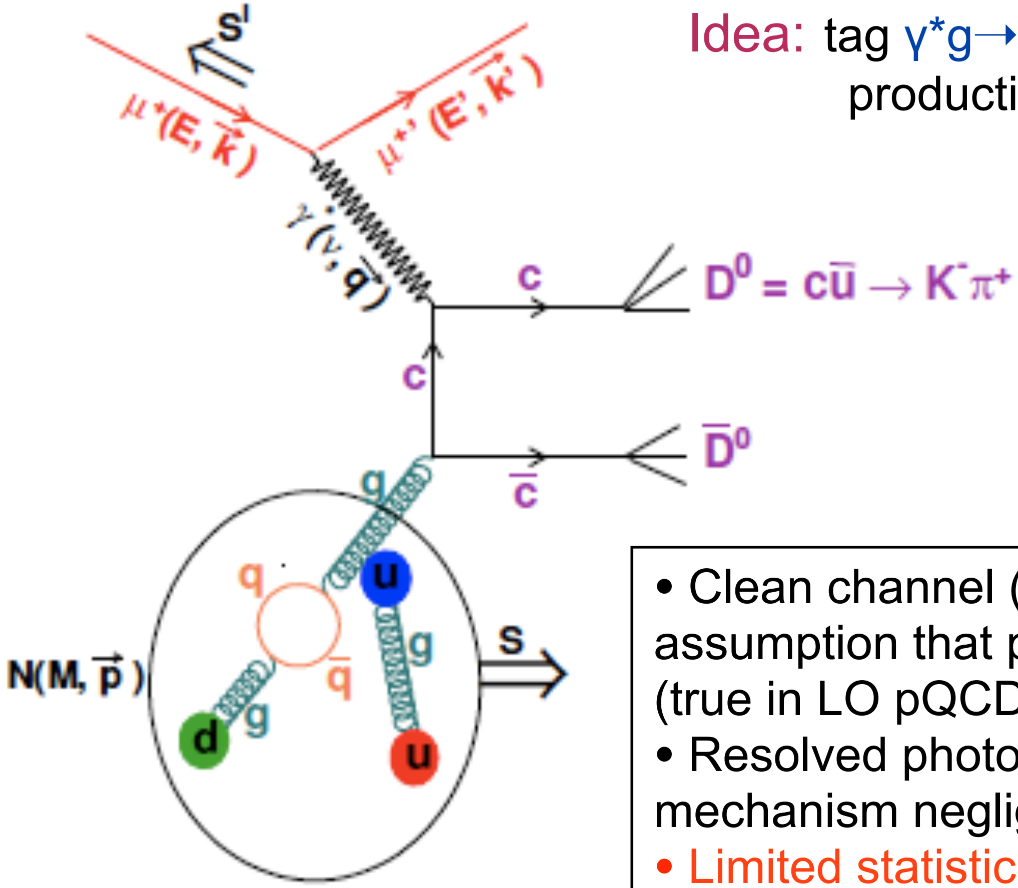
APV electronics in periphery

Contents

- COMPASS experiment
- Charmed meson reconstruction at COMPASS
- Signal to background parameterization

- New channels from D^*: π^0 reflection "bump" and "RICH sub-threshold kaons events"
- Neural network approach to signal/background parameterization
- New $\Delta G/G$ result in LO

- Asymmetries from open-charm
- $\Delta G/G$ in LO approximation from COMPASS main D^0 and D^* channels
- Summary and plans



Idea: tag $\gamma^* g \to c c_{bar}$ via open-charm production mechanism

COMPASS: PLB676(2009)31

- Clean channel (less MC dependent) under the assumption that production mechanism is PGF only (true in LO pQCD)
- Resolved photon and "intrinsic" charm production mechanism negligible in COMPASS kinematics
- Limited statistics (no vertex detector - long polarized target)
- Huge combinatorial background
- NLO corrections potentially important

$$A^{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = P_B\, P_T\, f\, a_{LL} \frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_{bgd}} \frac{\Delta g}{g} + A^{bgd}$$

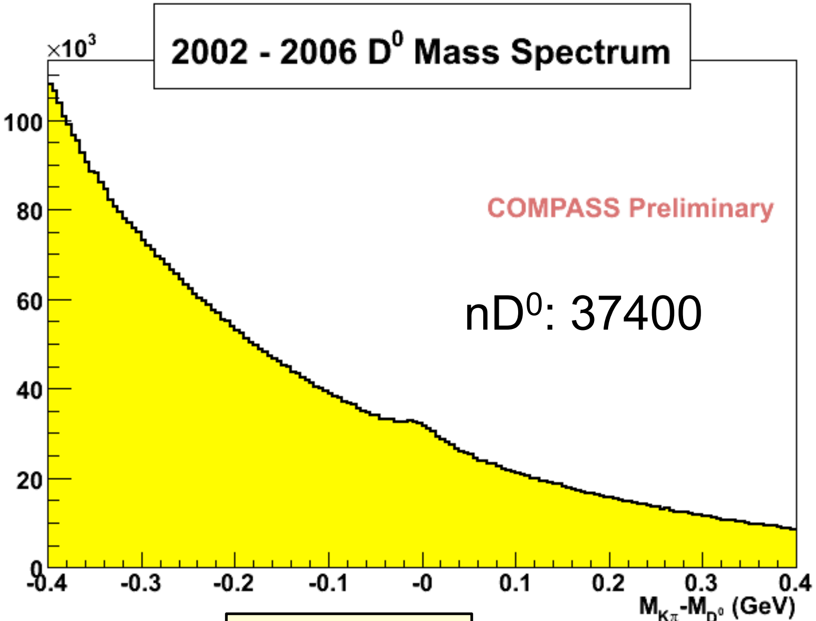
P_B, P_T - are beam and target polarizations,
f - dilution factor (~0.4 for ^{6}LiD target)
a_{LL} is a partonic asymmetry (analyzing power) for subprocess: $\mu g \rightarrow c c_{bar} \mu'$

- $\frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_{bgd}}$ is parameterized in terms of 10 variables, not just as a function of the reconstructed mass.
- each event is weighted with its analyzing power:
  $$f\, P_B\, a_{LL} \frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_{bgd}}$$
  Large gain in statistics (a_{LL} has positive and negative values)
- events are simultaneously weighted with $(\ldots \frac{\sigma_{BGD}}{\sigma_{PGF}+\sigma_{bgd}})$
  $\Rightarrow$ allows simultaneous extraction of signal and background asymmetries,
  more efficient than side band subtraction

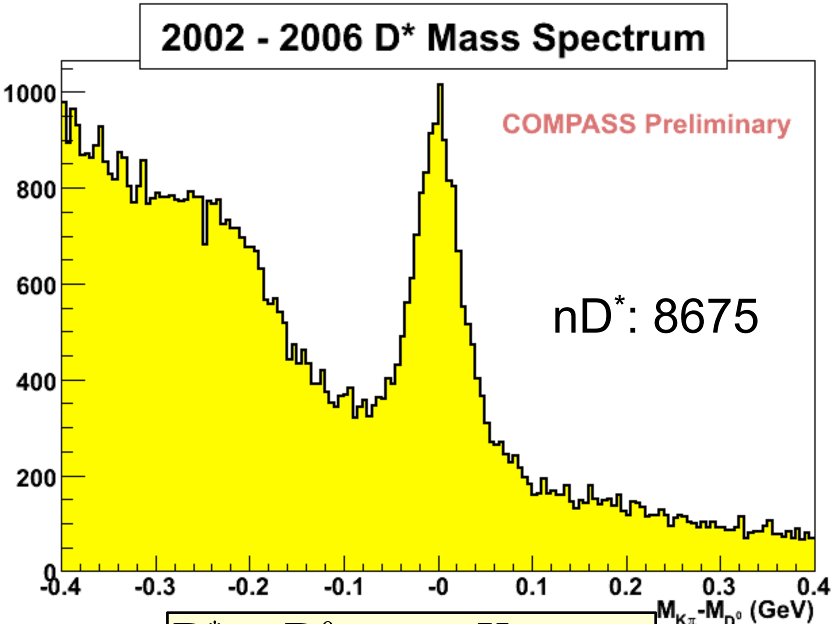
D^0 and D^* meson reconstruction

- **Events considered** *(resulting from c quarks fragmentation):*
  - $D^0 \to K\pi$ *(BR: 4%)*
  - $D^* \to D^0\pi_s \to K\pi\pi_s$ *(30% D^0 tagged with D^*)*
- **Selection to reduce the combinatorial background:**
  - Kinematical cuts: Z_D, D^0 decay angle, K and π momentum
  - RICH identification: K and π ID + electrons rejected from the π_s sample

Thick target - no D^0 vertex reconstruction
D^0 reconstruction: $K\pi$ invariant mass + cuts on D^0 decay angle + z_D + RICH particle identification (different likelihoods)



$D^0 \to K + \pi$



$D^* \to D^0 + \pi_s \to K + \pi + \pi_s$

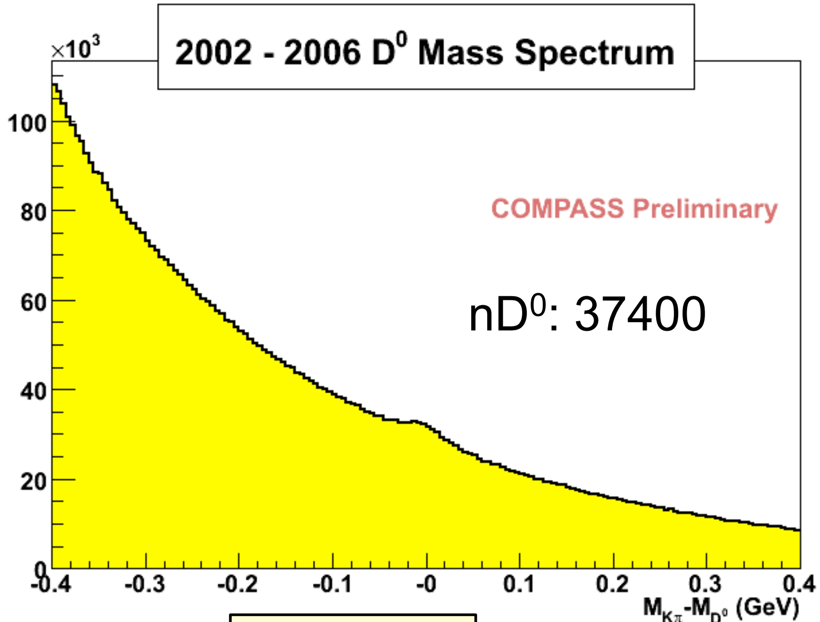
+2 more channels :

- $D^0 \to K^-\pi^+ + (\pi^0)$
- $D^{*+} \to D^0\pi^+_{soft} \to K^-\pi^+\pi^+_{soft}$ (with kaons below RICH threshold of 9 GeV)

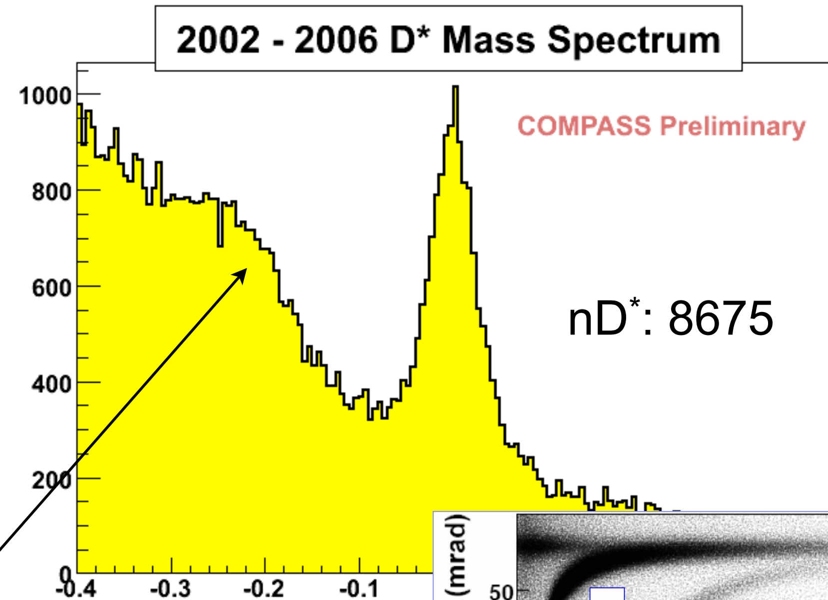
New!

Thick target - no D^0 vertex reconstruction

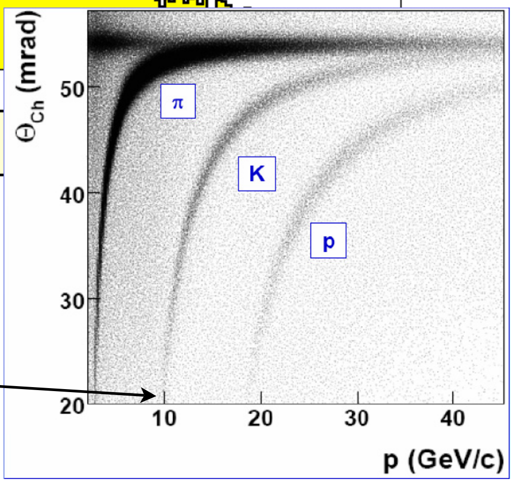
D^0 reconstruction: $K\pi$ invariant mass + cuts on D^0 decay angle + z_D + RICH particle identification (different likelihoods)



$D^0 \to K + \pi$



$D^* \to D^0 + \pi_s$



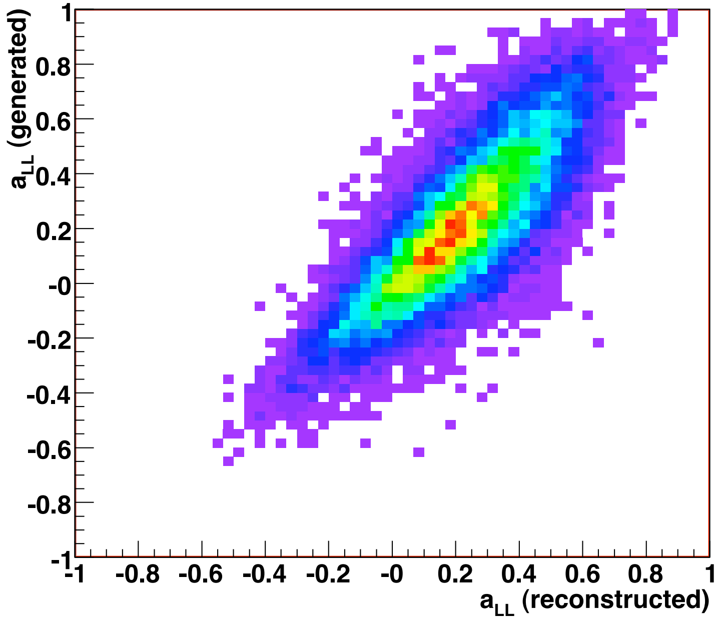
+2 more channels :

- $D^0 \to K^-\pi^+ + (\pi^0)$
- $D^{*+} \to D^0\pi^+_{soft} \to K^-\pi^+\pi^+_{soft}$ (with kaons below RICH threshold of 9 GeV)

- **a_{LL} is dependent on full knowlege of partonic kinematics:**
  - $a_{LL} = \frac{\Delta \sigma^{PGF}}{\sigma_{PGF}} (y, Q^2, x_g, z_C, \phi)$
  - Can't be experimentally obtained! ⇒ only one charmed meson is reconstructed

- a_{LL} is obtained from Monte-Carlo *(in LO)*, to serve as input for a Neural Network parameterization on reconstructed kinematical variables: y, x_{Bj}, Q^2, z_D and $p_{T,D}$

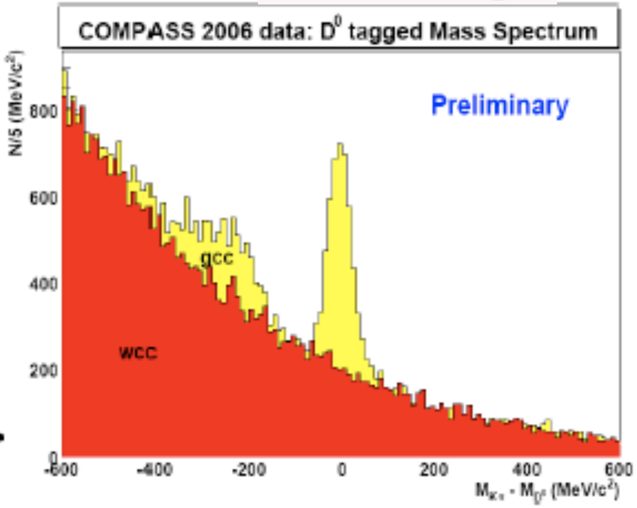
- 82% correlation NN/MC
- very large dispersion of values, even change of sign: weighting essential



- **Two real data samples** *(with same cuts)* **are compared by the Neural Network** *(giving as input some kinematic variables as a learning vector)*:
  - **Signal model** → **gcc** $= K^{+}\pi^{-}\pi_s^{-} + K^{-}\pi^{+}\pi_s^{+}$ *(D^* spectrum: signal + bg.)*
  - **Background model** → **wcc** $= K^{+}\pi^{+}\pi_s^{-} + K^{-}\pi^{-}\pi_s^{+}$
- **If the background model is good enough:** Net is able to distinguish the signal from the combinatorial background on a event by event basis!
- **Σ is built in the same way as for main channels, BUT:**

$$\Sigma = \frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_{bgd}}$$

  - Only 1variable is used: Neural Network output
    - Sorts the events according to similar kinematic dependences *(thus improving our statistical precision)*
    - Results from 2 real data samples comparison, in a mass window around the meson mass



New preliminary result including all channels

$$\Delta G/G = -0.39 \pm 0.24 \text{ (stat)}$$

published: $\Delta G/G = -0.49 \pm 0.27 \text{ (stat)} \pm 0.11 \text{ (syst)}$

$$\langle x_g \rangle = 0.11^{+0.11}_{-0.05}$$
$$\langle \mu^2 \rangle = 13\, GeV^2$$

10% gain in statistical precision!

Summary

- Small value of ΔG/G is preferred - ΔG/G compatible with 0 within 2σ
- Under study:
  - pure NN approach (fit independent)
  - 2007 data (proton)
  - others channels (4 particles from decay)
  - NLO analysis

- Part II - *NLO QCD predictions for gluon polarization from open-charm asymmetries measured at COMPASS*

- Model independent asymmetries were extracted from data only

$$A_{\exp} = P_B P_T f \left[R_{PGF} D A^{\gamma N \to DX} + (1 - R_{PGF}) A_{bkg} \right]$$

- $\frac{\Delta g}{g}$ can be extracted using a_{LL}^{PGF} calculated at LO :

published: PLB676(2009)31

$$A_{\exp} = P_B P_T f \left[R_{PGF} \, a_{LL}^{PGF} \frac{\Delta g}{g} + (1 - R_{PGF}) A_{bkg} \right]$$

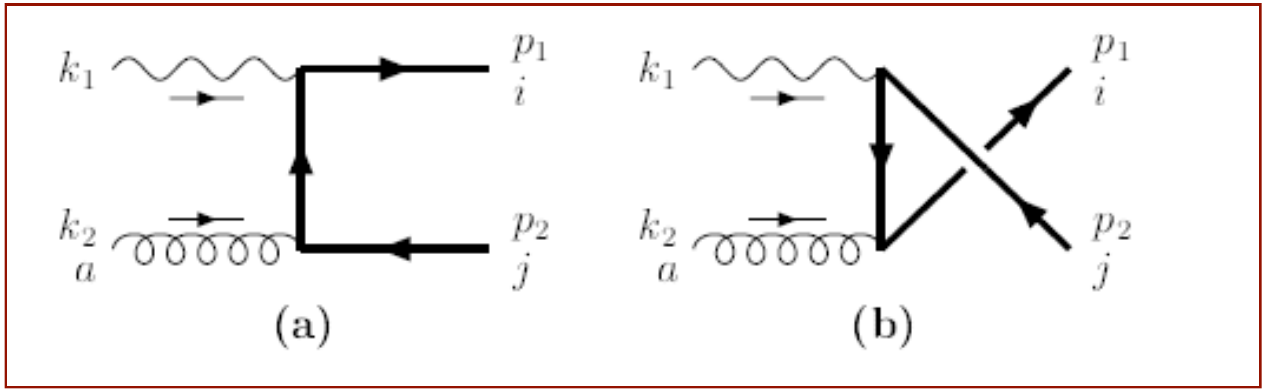
- Similar analysis, but with weight $$w = f \, P_B \frac{S}{S+B} a_{LL}$$

instead of $$w = f \, P_B \frac{S}{S+B} D$$

Contents

- LO and NLO QCD processes for open-charm production
- The role of MC in the COMPASS open-charm analysis
- NLO corrections and the MC approach
- $\Delta G/G$ in the NLO approximation from COMPASS open-charm asymmetries
- Summary

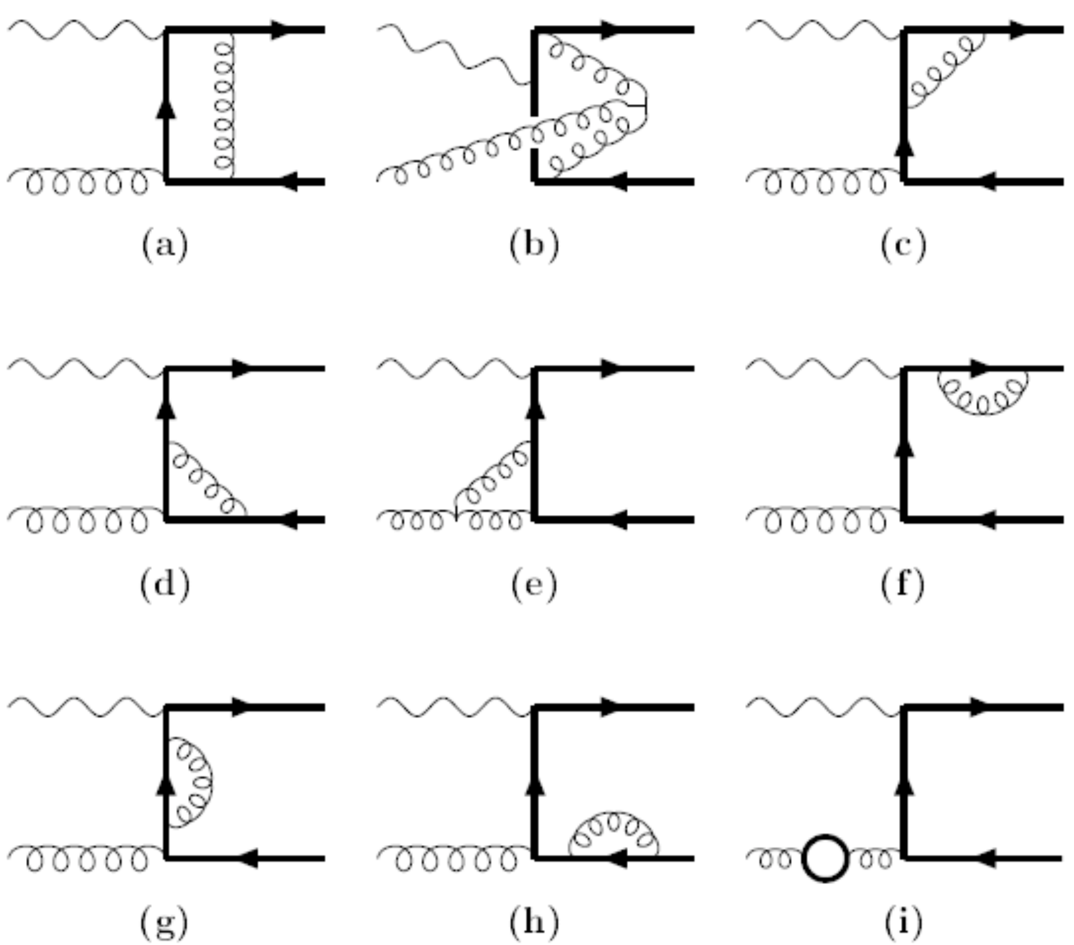
LO subprocesses for charm production – only PGF,
No light quarks contribution – means no „physical background"



Simple expresion for analysing power even if mass of muon and Q^2 dependence is taken into account – used in the present COMPASS analysis (published)

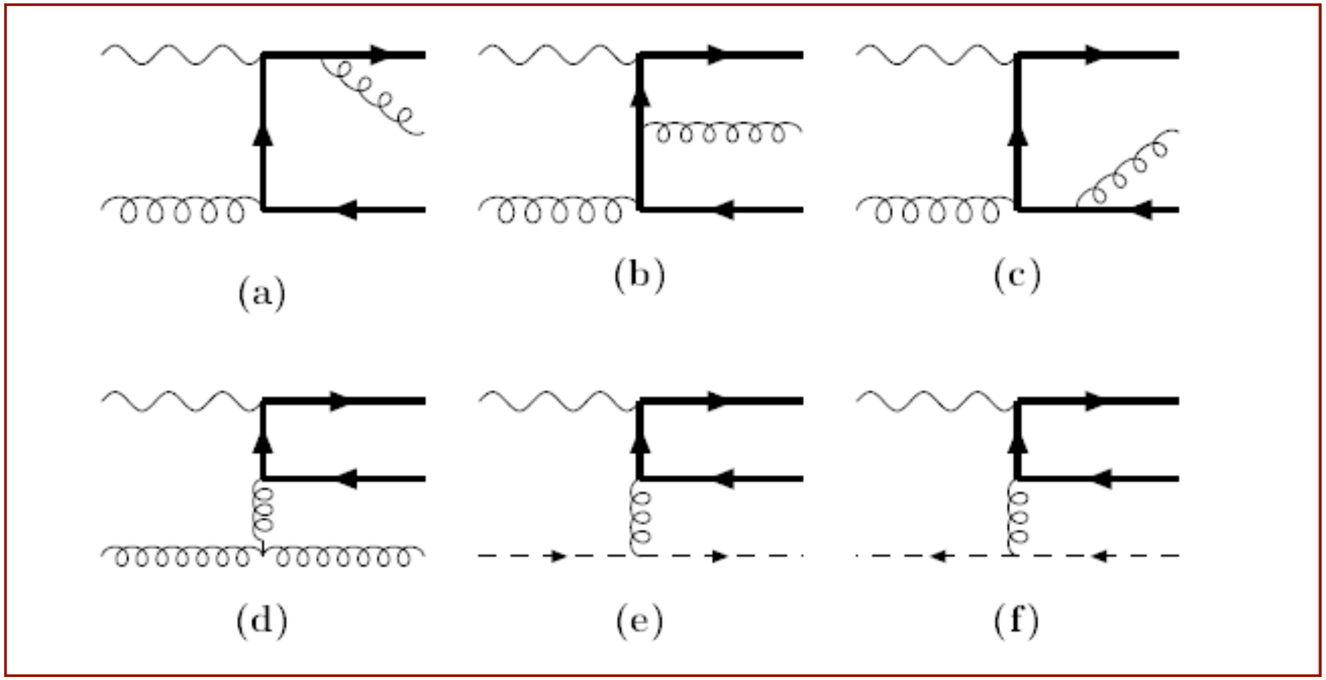
NLO calculations for partonic cross sections – much more complicated. Here Feynmamn diagrams for „virtual +soft" corrections are presented.

Loops produce divergences:
UV – removed by renormalization procedure,
IR - related to „zero" momenta of Internal loop particles



NLO calculations for partonic cross sections.
Here Feynmamn diagrams for „hard gluon emissions” corrections.

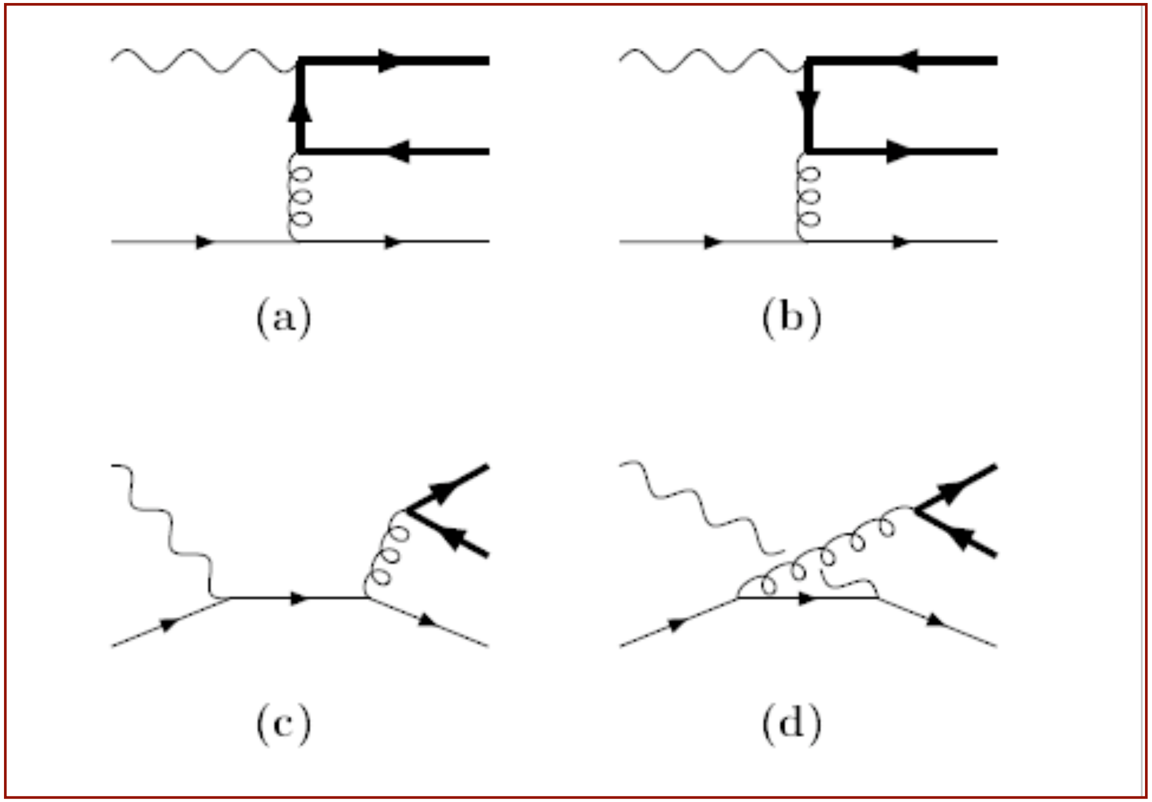
IR - related to „soft” momenta of gluon emissions. Here there is also colliner divergency for 3-gluons coupling



„VS” and „Hard” parts contain so-called double pole: $\sim \frac{1}{\varepsilon_{UV}} \frac{1}{\varepsilon_{IR}}$

These terms MUST cancell Factorization.

NLO calculations for partonic cross sections originated from light quarks.
No LO corresponding process!
New channel which produces „physical background"



Not discussed in this talk - only NLO to PGF.

The structure of the cross sections in NLO QCD

$$\frac{\sigma^{NLO}}{dt_1 du_1} = \frac{\alpha\alpha_S^2 e_q^2}{s^2}\left(\sigma_{Hard}^{non-abelian} + \sigma_{Hard}^{QED} + \sigma_{SV}^{non-abelian} + \sigma_{SV}^{QED} + \sigma^F \log(\frac{\mu_f^2}{m^2})\right)$$

$$\frac{\Delta\sigma^{NLO}}{dt_1 du_1} = \frac{\alpha\alpha_S^2 e_q^2}{s^2}\left(\Delta\sigma_{Hard}^{non-abelian} + \Delta\sigma_{Hard}^{QED} + \Delta\sigma_{SV}^{non-abelian} + \Delta\sigma_{SV}^{QED} + \Delta\sigma^F \log(\frac{\mu_f^2}{m^2})\right)$$

Kinematics:

$$s + t_1 + u_1 = 0$$ ← for LO and „SV" NLO part

$$s + t_1 + u_1 = s_4$$ ← for „Hard" NLO part (integration over s_4)

$$t_1 = t - m^2 \qquad u_1 = u - m^2$$

I.Bojak, M.Stratmann, hep-ph/9807405,
Nucl.Phys.B 540 (1999) 345, I.Bojak, PhD thesis
J.Smith, W.L.Neerven, Nucl.Phys.B 374 (1992)36)
W.Beenakker, H.Kuijf, W.L.Neerven,,J.Smith, Phys.Rev.D40(1989)54

1. NLO corrections available only for photo-producion limit. $Q^2 = 0$
2. No big problem for COMPASS: D – depolarization factor

$$a_{LL}^{LO} = D a_{LL}^{LO,\gamma g}$$

$$a_{LL}^{NLO} = D a_{LL}^{NLO,\gamma g}$$

Neglecting Q^2 in this parts is not a big sin – unimportant effect ☺

$a_{LL}^{NLO,\gamma g}$ Calculated in NLO with the assumptions of photo-production.

$$A = \frac{\int \Delta G(x_g)\Delta\hat{\sigma}^{LO} du_1 dt_1}{\int G(x_g)\hat{\sigma}^{LO} du_1 dt_1} = \frac{\int \frac{\Delta G}{G} \frac{\Delta\hat{\sigma}^{LO}}{\hat{\sigma}^{LO}} G(x_g)\hat{\sigma}^{LO} du_1 dt_1}{\int G(x_g)\hat{\sigma}^{LO} du_1 dt_1}$$

$$A = < \frac{\Delta G}{G} \frac{\Delta\sigma^{LO}}{\sigma^{LO}} > = < \frac{\Delta G}{G} > < \frac{\Delta\hat{\sigma}^{LO}}{\hat{\sigma}^{LO}} > = < \frac{\Delta G}{G} > < a_{LL}^{LO} >$$

$$< \frac{\Delta G}{G} > = \frac{\int \frac{\Delta G}{G} a_{LL}^{LO} G(x_g)\hat{\sigma}^{LO} du_1 dt_1}{\int a_{LL}^{LO} G(x_g)\hat{\sigma}^{LO} du_1 dt_1} = \frac{\Delta G}{G}(< x_g >)$$

$$\frac{\Delta G}{G} \approx a(x_g - < x_g >) + b \qquad b = \frac{\Delta G}{G}(< x_g >)$$

$$< x_g > = \frac{\int x_g a_{LL}^{LO} G(x_g)\hat{\sigma}^{LO} du_1 dt_1}{\int a_{LL}^{LO} G(x_g)\hat{\sigma}^{LO} du_1 dt_1}$$

$$< a_{LL}^{LO} > = \frac{\int a_{LL}^{LO} G(x_g)\hat{\sigma}^{LO} du_1 dt_1}{\int G(x_g)\hat{\sigma}^{LO} du_1 dt_1}$$

The role of MC and theoretical input

- a_{LL} allows to calculate gluon polarization from measured asymmetries
- COMPASS is using weighted method - and a_{LL} (theory input) is used in the weight. To calculate a_{LL} MC generator with simulation of the apparatus + reconstruction is used; then a_{LL} is parameterized and run on real data to estimate a_{LL} event by event.
- The weight has impact on value, statistical error and $\langle x_G \rangle$!
- Changing approximation (from a_{LL} in LO to NLO) can have a serious consequence on importance and precision of the COMPASS result!

Procedure in NLO

- MC with parton shower (MC PS on) to simulate phase space for real emissions
- events have s_1,u_1 and t_1 and $s_1+t_1+u_1 \neq 0$
- Method 1:
  event is defined by cc_{bar} system: u_1 and t_1 define event.
  Integrations over s_4 is performed from 0 up to $s_1+t_1+u_1$
- Method 2:
  event is defined by s_1 and $t_1(u_1)$ - only one charm observed.
  Integration over s_4 is performed from 0 up to $s_1+t_1+u_1$

method 1

- Advantage: similar to theoretical calculations in bins - gluons convoluted with hard part in the integration over s_4 - good for collinear divergence removal procedure
- Disadvantage: shape of gluon distribution is required - model of gluon polarization needed!
- Assumption done: MC with PS on reproduces correctly the event distributions produced according to $\sigma^{NLO} * G(s_1^{el})/G(s_1)$

method 2

- Advantage: model of gluons is not needed. Method is similar to LO approach
- Disadvantage: hard part is not convoluted with gluon distribution what is slightly inconsistent. Kinematics of the second charm in the event ignored - not observed as in real data.
- Assumption done: MC with PS on reproduces correctly the event distributions produced according to σ^{NLO}

method 1 - examples

- Model of the gluon polarization:
  1. ΔG/G=const,
  COMPASS QCD fits:
  2 - positive gluons
  3 - negative gluons
- used to ilustrate the potential differences between methods based on the same MC events, good for systematic studies

MC input: a_{LL} calculation

- This part of the talk is not on behalf of COMPASS - pure MC generator (aroma) has been used -no acceptance/reconstruction/apparatus simulation used.
- But - it is not crucial thanks to weighting!
- Tested and compared for LO results
- PDF unpolarized used: MRST2004 LO/NLO, GRV98 LO
- Scale: $2m_c$
- No special cuts except cut on energy of the E_D
- MC used only for signal simulation: PSoff/on (LO/NLO)
- s/(s+b) assumed 1 (no background simulation) - therefore statistical error is smaller than in COMPASS analysis

based on 2002-2006 COMPASS data and published asymmetries in bins (PLB 676(2009)31)

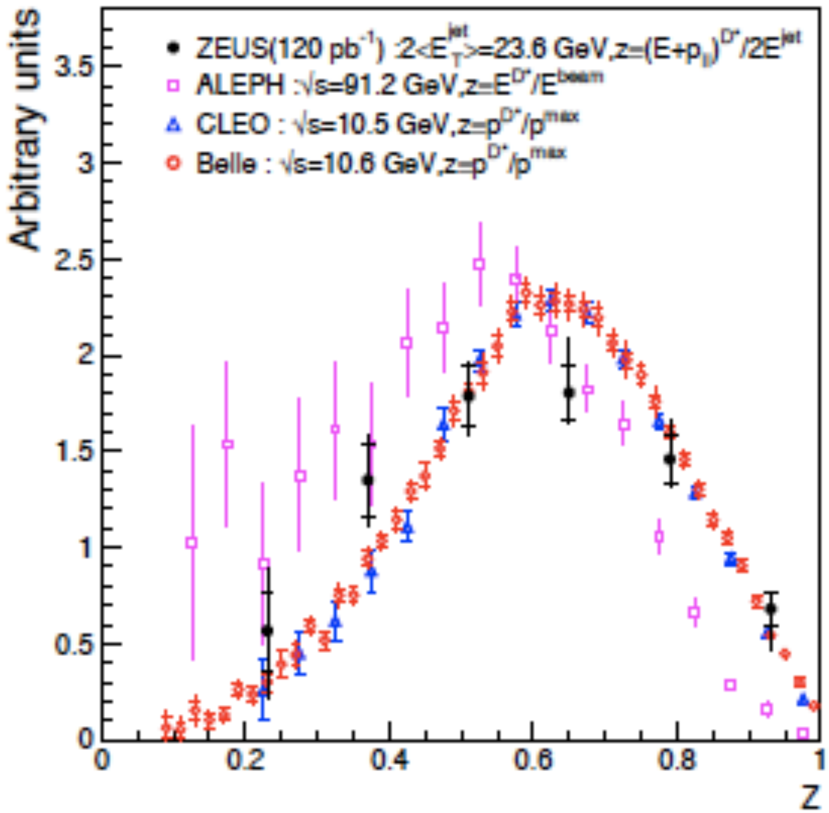
- LO weighted from PLB ΔG/G=-0.49±0.27
- LO (from asym. and a_{LL} from PLB) ΔG/G=-0.42±0.28
- LO (MC PSoff, asym. from PLB): ΔG/G=-0.47±0.23

- NLO (MC PSon, asym. from PLB)
- method 2: ΔG/G=+0.032±0.231
- ΔG/G=const (method 1): ΔG/G=-0.051±0.239
- ΔG/G>0, Compass fit (method 1): ΔG/G=-0.036±0.239
- ΔG/G<0, Compass fit (method 1): ΔG/G=-0.057±0.240

Comment:

- MC with PS on simulates NLO kinematics of the event in the approximation (Sudakov formfactor approach)
- MC is in still in LO approx.,PS - depends on MC steering parameters.
- Another approach: simple MC generator weighted by correct NLO cross section
- Belle D^*/D^0 fragmentation function

Peterson set with slightly modified parameters to describe Belle data

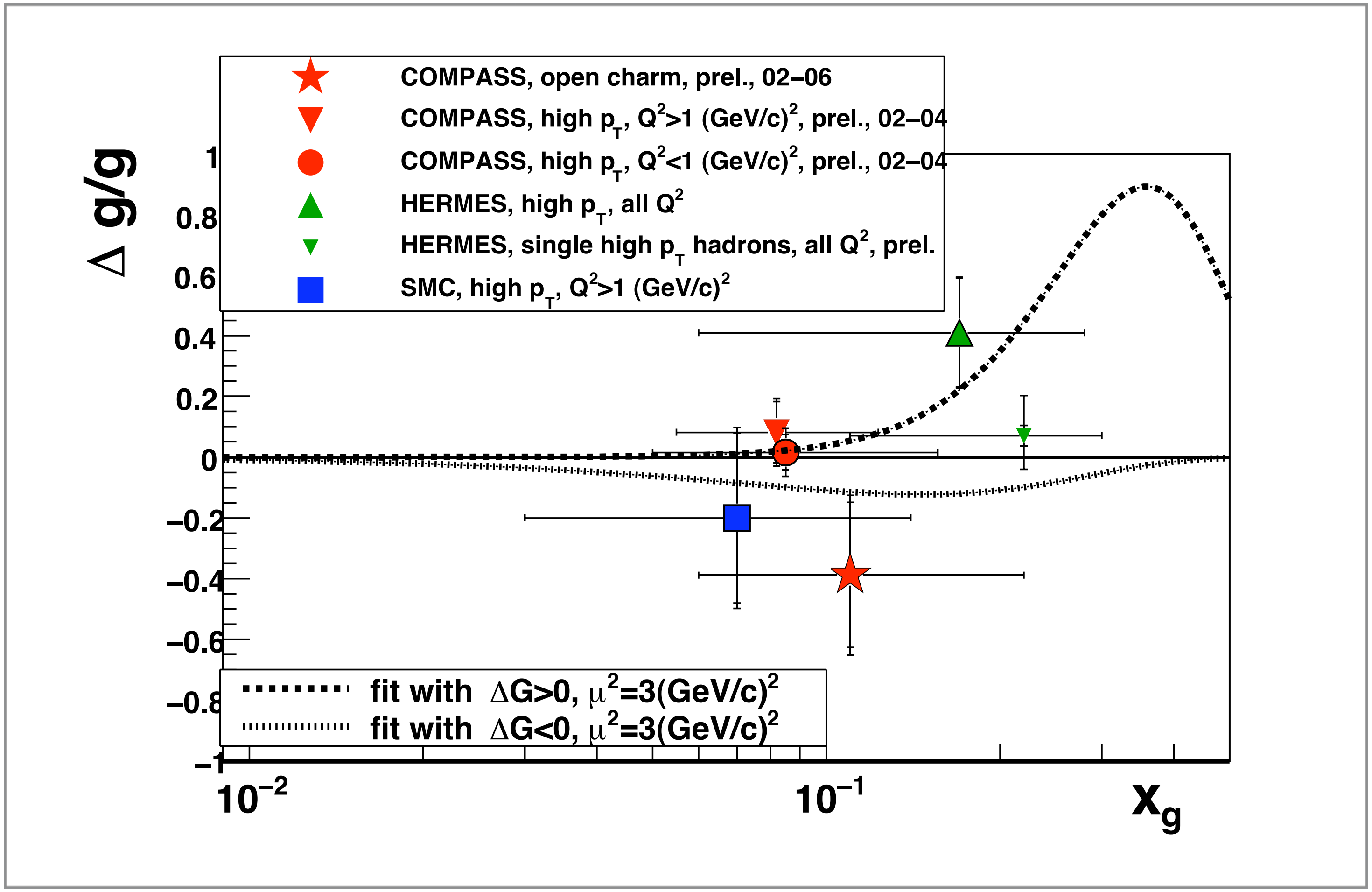


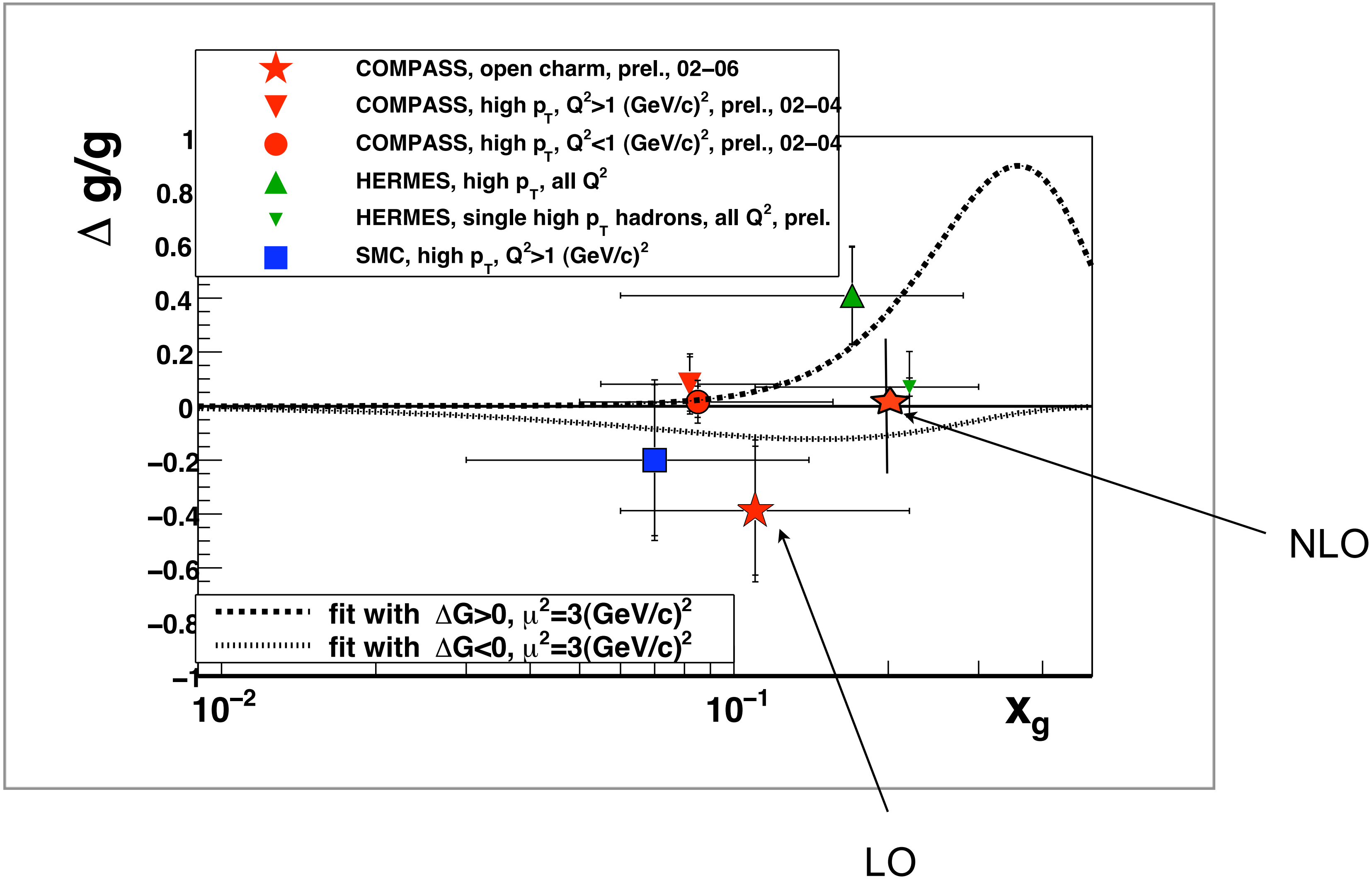
Fragmentation function	Functional form	Comment
Bowler	$N \frac{1}{z^{1+bm^2}}(1-z)^a \exp(-\frac{bm_\perp^2}{z})$	a, b identical for all quarks
Lund	$N \frac{1}{z}(1-z)^a \exp(-\frac{bm_\perp^2}{z})$	a, b identical for all quarks
Kartvelishvili	$N z^{\alpha_c}(1-z)$	
Collins-Spiller	$N(\frac{1-z}{z} + \frac{(2-z)\varepsilon'_c}{1-z})(1+z^2)(1-\frac{1}{z}-\frac{\varepsilon'_c}{1-z})^{-2}$	
Peterson	$N \frac{1}{z}(1-\frac{1}{z}-\frac{\varepsilon_c}{1-z})^{-2}$	widely used

- Full NLO cross section weighted MC - with special attention to high s_4 - very energetic gluon emission (not generated in PS approach)

- Fragmentation function from Belle, simple independent fragmentation
- p_T generated by hard process from charm quark
- small p_T effect in fragmentation assumed

- method 2 (no gluon shape needed): $\Delta G/G = +0.005 \pm 0.22$
  - in good agreement with MC PS on result


COMPASS, open charm, prel., 02–06
COMPASS, high p_T, Q^2>1 (GeV/c)^2, prel., 02–04
COMPASS, high p_T, Q^2<1 (GeV/c)^2, prel., 02–04
HERMES, high p_T, all Q^2
HERMES, single high p_T hadrons, all Q^2, prel.
SMC, high p_T, Q^2>1 (GeV/c)^2
$\Delta g/g$
1
0.8
0.6
0.4
0.2
0
–0.2
–0.4
–0.6
–0.8
–1
fit with $\Delta G>0$, μ^2=3(GeV/c)^2
fit with $\Delta G<0$, μ^2=3(GeV/c)^2
10^{-2}
10^{-1}
x_g



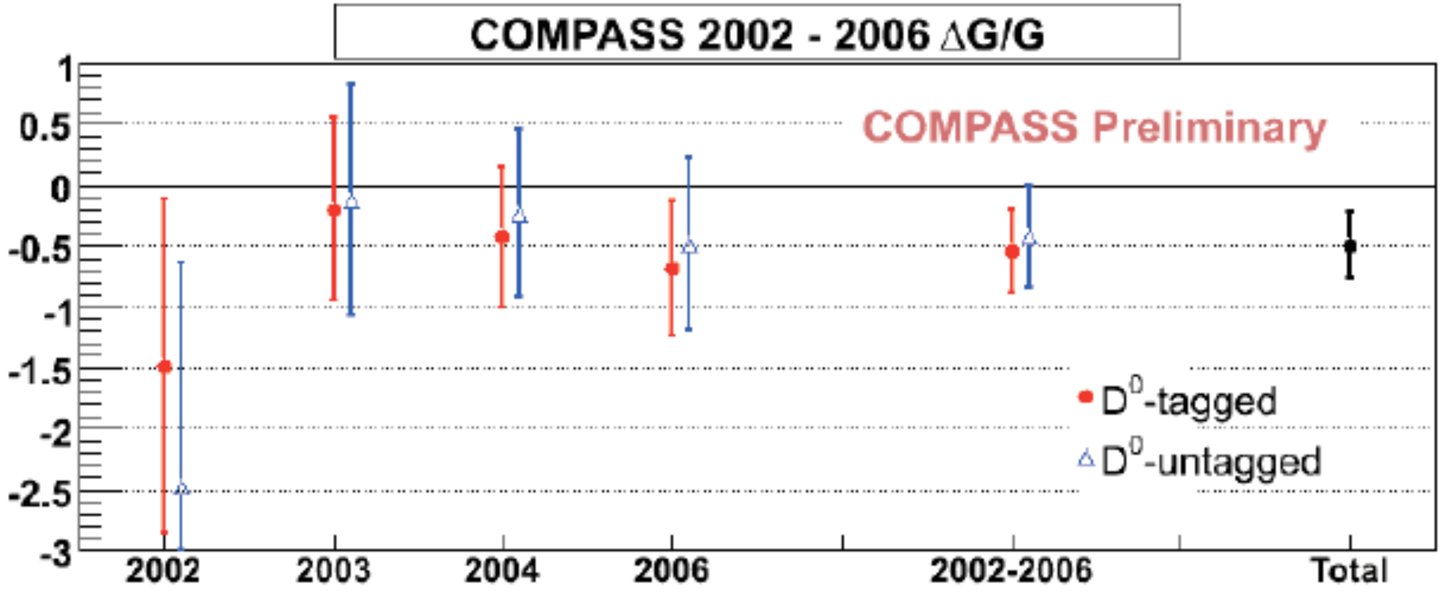
COMPASS, open charm, prel., 02–06
COMPASS, high p_T, Q^2>1 $(GeV/c)^2$, prel., 02–04
COMPASS, high p_T, Q^2<1 $(GeV/c)^2$, prel., 02–04
HERMES, high p_T, all Q^2
HERMES, single high p_T hadrons, all Q^2, prel.
SMC, high p_T, Q^2>1 $(GeV/c)^2$
$\Delta g/g$
1
0.8
0.6
0.4
0.2
0
–0.2
–0.4
–0.6
–0.8
–1
fit with $\Delta G>0$, $\mu^2=3(GeV/c)^2$
fit with $\Delta G<0$, $\mu^2=3(GeV/c)^2$
10^{-2}
10^{-1}
x_g
NLO
LO

Conclusions

- NLO corrections for a_{LL} (PGF channel) for COMPASS open-charm asymmetry bins have been computed based on MC PS on and MC weighted by correct NLO cross section
- Preliminary result for gluon polarization has been shown - gluon polarization consistent with 0.

- Missing NLO corrections - quark initiated processes - are under consideration

Spares



$$\Delta G/G = -0.49 \pm 0.27\ (\text{stat}) \pm 0.11\ (\text{syst})$$

Systematics :

Source	D^0	D^*
Beam polar	0.025	0.025
Target polar	0.025	0.025
Dil. Fact.	0.025	0.025
False asymmetry	0.05	0.05
Signal extraction (Σ)	0.07	0.01
a_{LL} (charm mass)	0.05	0.03
TOTAL	**0.11**	**0.07**

$$\langle x_g \rangle = 0.11^{+0.11}_{-0.05}$$

$$\langle \mu^2 \rangle = 13\, GeV^2$$

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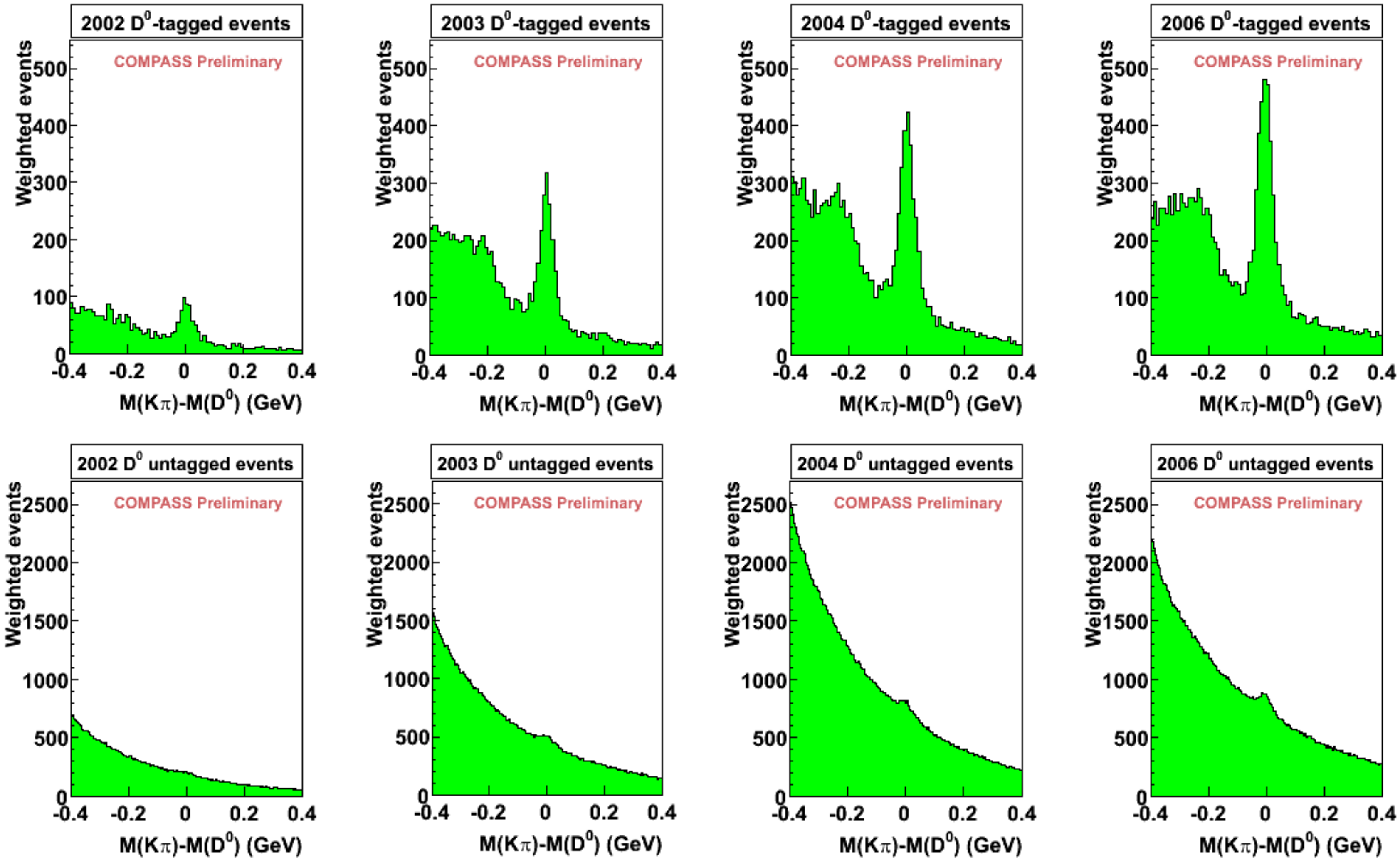
Open-charm signal - per year

Kπ invariant mass weighted spectra

	2002	2003	2004	2006
	$0.43\ fb^{-1}$	$0.58\ fb^{-1}$	$0.92\ fb^{-1}$	$0.85\ fb^{-1}$

D^*

D^0



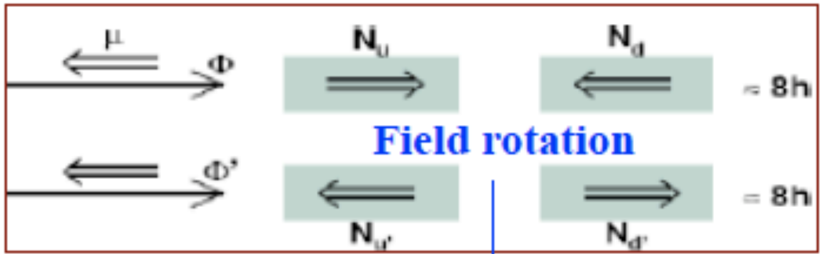
Considering $A_B = 0$

$$\frac{\Delta G}{G} = \frac{1}{2P_T P_\mu f a_{LL} \frac{S}{S+B}} \times \left(\frac{N^u - N^d}{N^u + N^d} + \frac{N^{d'} - N^{u'}}{N^{u'} + N^{d'}} \right)$$

event weight

partonic asymmetry

signal strength of Open-Charm events



equal acceptance for both cells

- **Using** →

$$A_1 \overset{\text{LO}}{=} \langle a_{LL} \rangle \langle \frac{\Delta G}{G} \rangle \quad \text{with} \quad a_{LL} = \frac{\Delta \sigma^{PGF}}{\sigma^{PGF}}$$

asymmetries are less sensitive to experimental changes than cross section differences

- **Events with small** $(P_\mu \cdot P_T \cdot f \cdot a_{LL} \cdot (S/S+B))$ **factors contain less information about the asymmetry:**
  - Weighting the events with the option choosen minimizes de statistical error

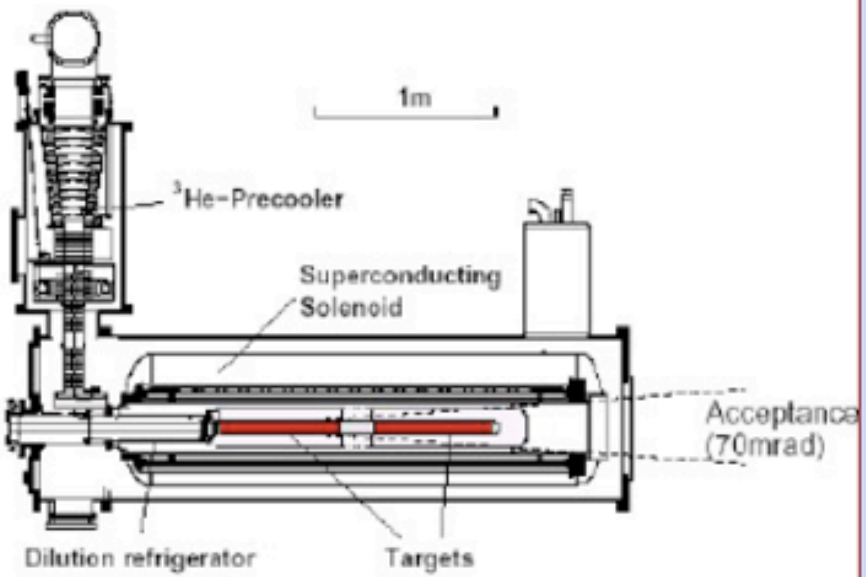
$$\frac{\Delta G}{G} = \frac{1}{2P_T} \times \left(\frac{\omega_u - \omega_d}{\omega_u^2 + \omega_d^2} + \frac{\omega_{u'} - \omega_{d'}}{\omega_{u'}^2 + \omega_{d'}^2} \right) \text{ with a statistical gain} : \frac{\langle \omega^2 \rangle}{\langle \omega \rangle^2}$$

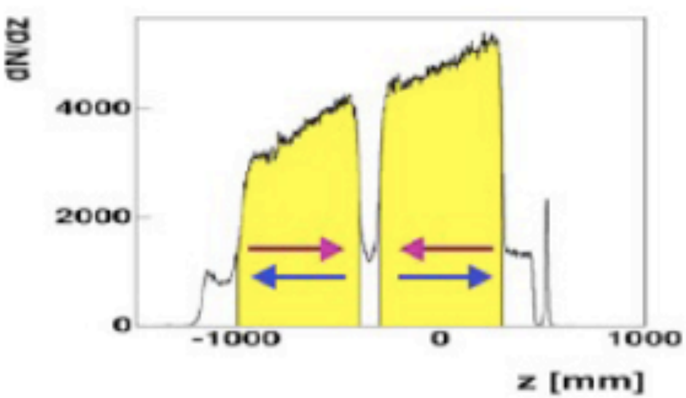
How to parameterize Σ ?

- **A function to build Σ_p = S/B is defined, and parameterized for every event:**
  - Σ_p is built *(iteratively)* over some kinematic variables and RICH response:
    - $(\Sigma_p)_{initial} = 1$
    - Mass spectra is divided in bins of each variable *(binning needed for statistical gain)*
    - Fit all D^0 and D^* mass spectra inside each bin of each variable
    - Σ_p is ajusted *(for every event inside each bin)* to $(S/B)_{fit}$
  - After convergence, parameterization is checked:
    - No artificial peak produced in wrong charge mass spectra
  - Mass dependence $\Rightarrow$ Included in Σ after convergence of Σ_p
  - $(\Sigma = \Sigma_p / \Sigma_p + 1)$ in the weight → **probability for a given event to be background or Open-Charm**

Polarised target

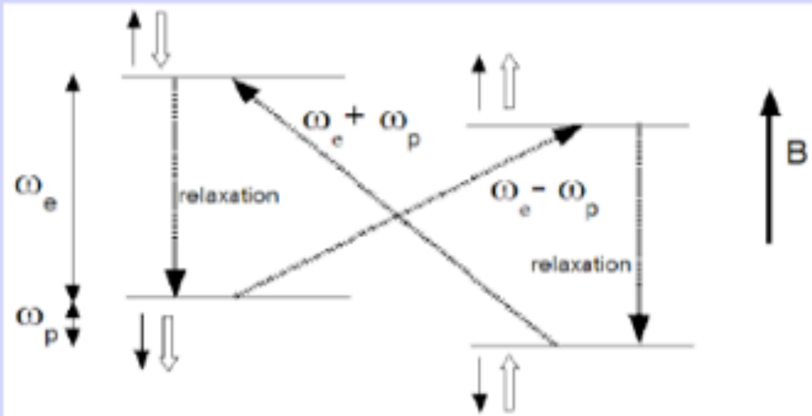
- Target material: ^{6}LiD
- Polarisation: $P_T > 50\%$
- Solenoid field: 2.5 T
- ^{3}He/^{4}He: $T_{min} \sim 50$ mK
- Dilution factor: $f \sim 0.4$





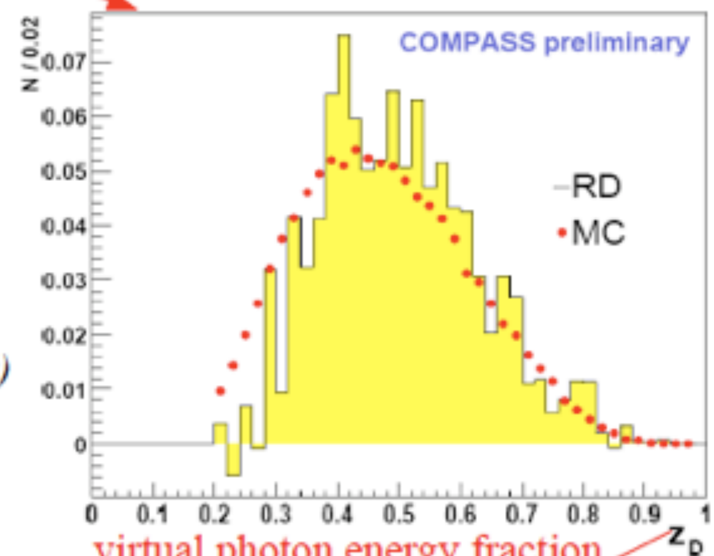
Dynamic nuclear polarisation:

- High electron polarisation *(high magnetic moment)*
- Microwave irradiation of material, for simultaneous flip of electron and nucleon spin
- After spin flip, electron relaxates to lower energy state
- Nucleon has long relaxation time *(low magnetic moment)*

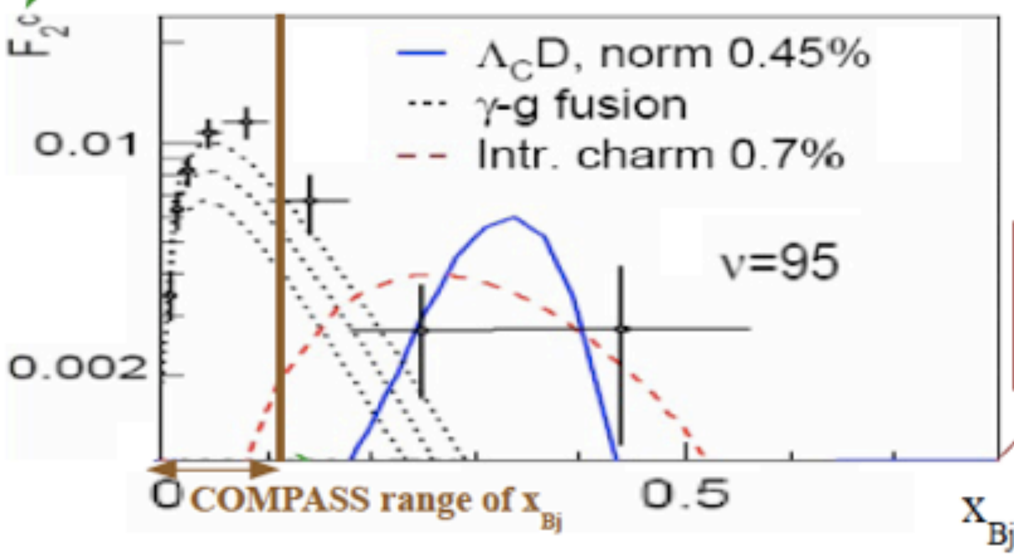


Why measure gluon spin from Open-Charm?

- $c\bar{c}$ production is dominated by the PGF process, and free from physical background *(ideal for probing gluon polarisation)*
  - In our center of mass energy, the contribution from intrinsic charm *(c quarks not coming from hard gluons)* in the nucleon is negligible
  - Perturbative scale set by charm mass $4m_c^2$
  - Nonperturbative sea models predict at most 0.7% for intrinsic charm contribution
    - Expected at high x_{Bj} *(compass x_{Bj} < 0.1)*
  - $c\bar{c}$ supressed during fragmentation *(at our energies)*



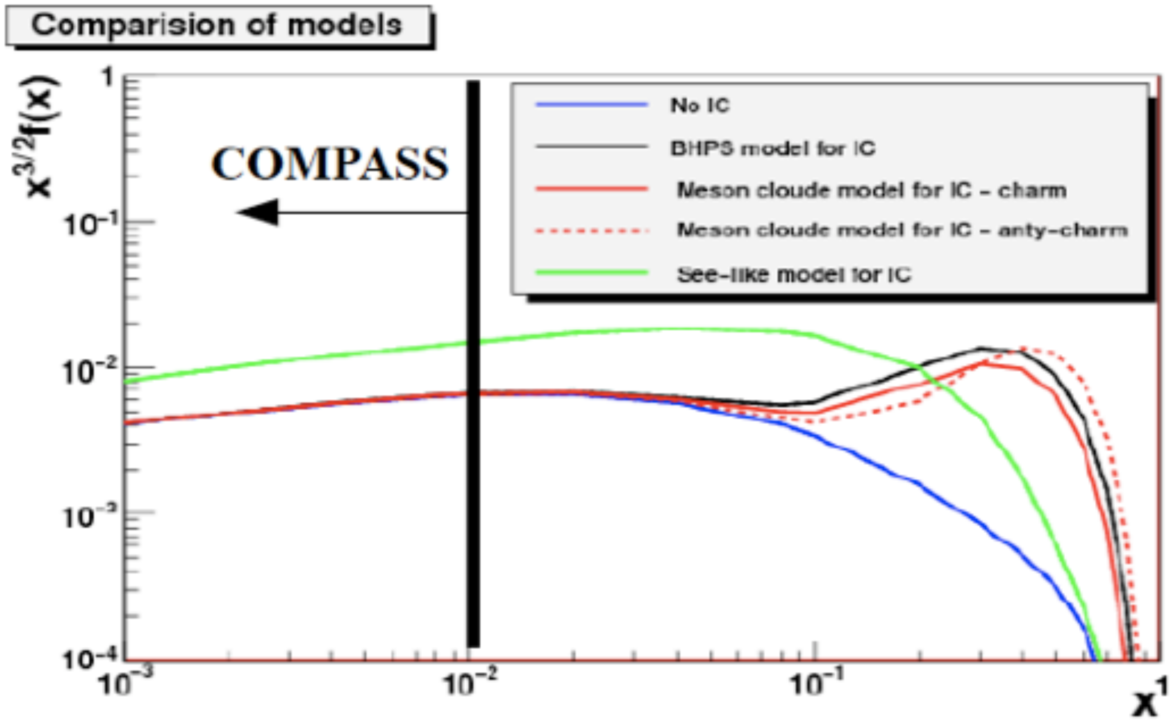
virtual photon energy fraction carried by D^0 meson

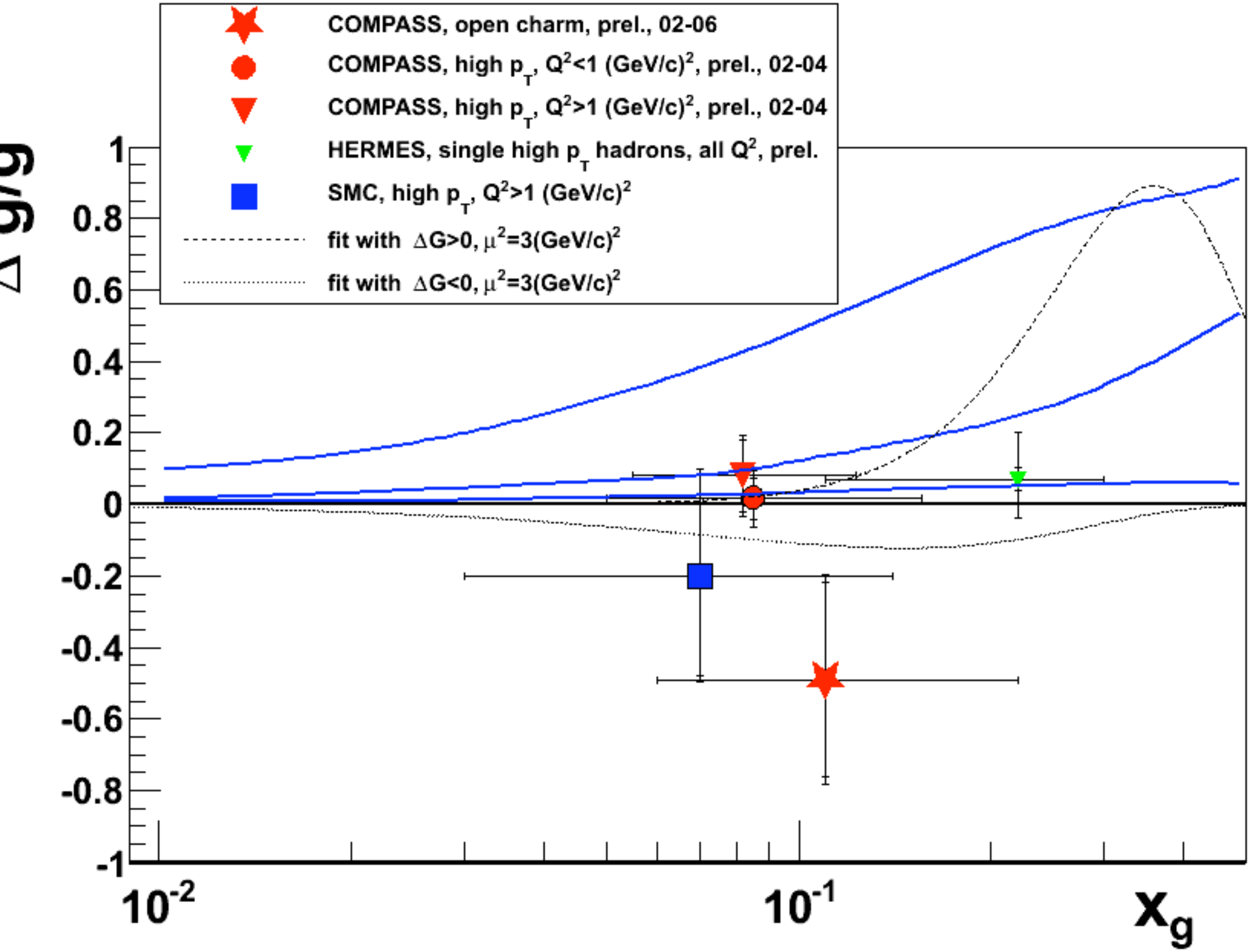


Ref. Hep-ph/0508126 and hep-ph/9508403
Phys. Lett. B93 (1980) 451
Data from EMC:Nucl.Phys.B213, 31(1983)

Intrinsic charm predictions: CTEQ6.5c

- **In the COMPASS kinematic domain:**
  - **No intrinsic charm contamination is predicted by the theory driven results**
  - **Only the more phenomenological *"See-like"* scenario should be taken into account *(under study)***





GRSV, ΔG

max, 2.5

std, 0.6

min, 0.2

Method for ΔG/G and polarised A_B extraction

- **The number of events comes from asymmetries in the following way:**

$$N_{u,d}=a\,\phi\,n(S+B)(1+P_T P_\mu f(a_{LL}\frac{S}{S+B}\frac{\Delta G}{G}+a_{LL}^{B}\frac{B}{S+B}A_B))$$

a = acceptance, ϕ = muon flux, n = number of target nucleons

- **We have 4 cell configurations** *(2 cells oppositely polarised + field reversal for acceptance normalization)*:
  - Weight the 4 $N_{u,d}$ equations by ω_s and by $\omega_B = P_\mu f\cdot D(y)$ (B/S+B)

$$<\sum_{k=1}^{N_{cell}}\omega_i^k>=\hat{a}_{cell,i}(1+(<\beta_{cell,S}>\omega_i)A_S+(<\beta_{cell,B}>\omega_i)A_B)=f_{cell,i}$$

(cell = u , d , u' , d') (ΔG/G) (i = S , B)

$$\hat{a}=a\,\phi\,n\,\sigma=a\,\phi\,n(\sigma_{PGF}+\sigma_B)=a\,\phi\,n(S+B)$$

$$\beta_S=P_B P_T f\,a_{LL}\frac{S}{S+B}\qquad \beta_S=P_B P_T f\,D\frac{B}{S+B}$$

8 eq. with 10 unknowns

How to solve equations for simultaneous $\Delta G/G$ and A_B extraction?

- **Possible acceptance changes with time are the same for both cells** *(also the muon flux is the same for both cells):*

  $10 \Rightarrow$ <u>8 unknowns</u>: 6 $\hat{a}$, A_S and A_B →
  $$\frac{\hat{a}_{u,S}\,\hat{a}_{d',S}}{\hat{a}_{u',S}\,\hat{a}_{d,S}} = 1 \quad , \quad \frac{\hat{a}_{u,B}\,\hat{a}_{d',B}}{\hat{a}_{u',B}\,\hat{a}_{d,B}} = 1$$

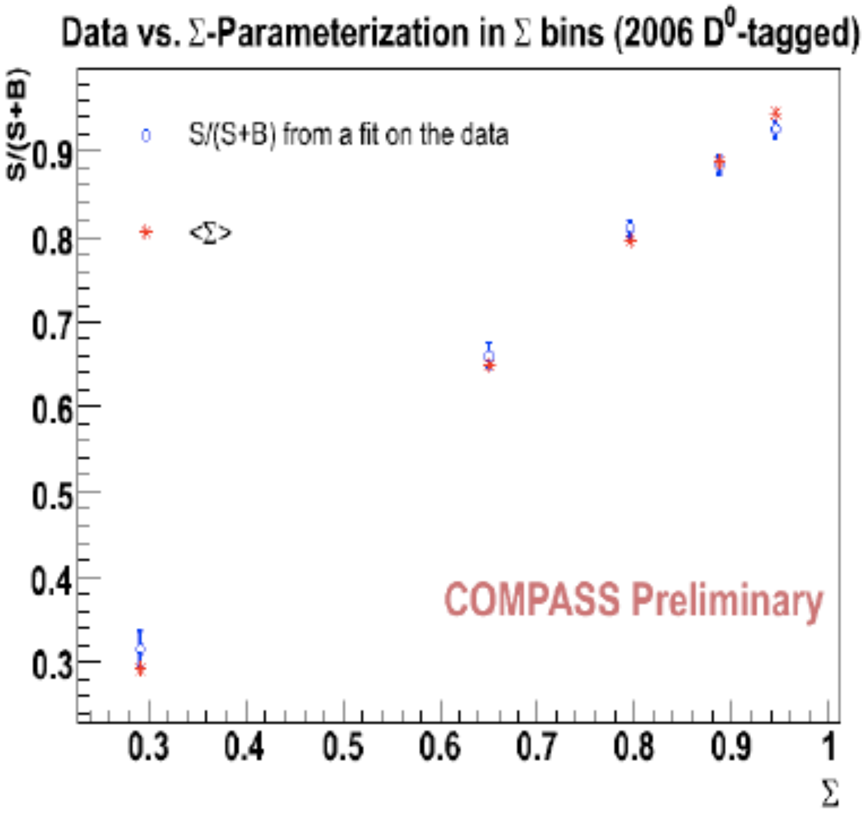
- **Signal and background events are affected in same way before and after a field reversal:**

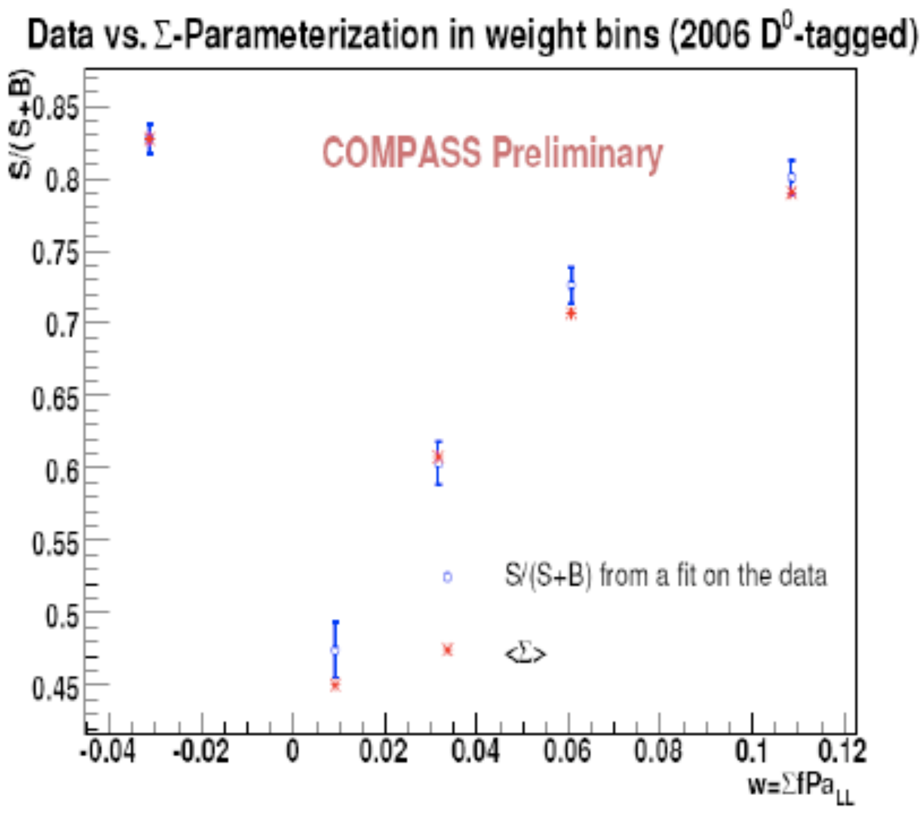
  $8 \Rightarrow$ <u>7 unknowns</u>: 5 $\hat{a}$, A_S and A_B →
  $$\frac{\hat{a}_{u,S}}{\hat{a}_{u,B}} = \frac{\hat{a}_{u',S}}{\hat{a}_{u',B}} \quad , \quad \frac{\hat{a}_{d,S}}{\hat{a}_{d,B}} = \frac{\hat{a}_{d',S}}{\hat{a}_{d',B}}$$

- **Unknowns are obtained by a χ^2 minimization:**

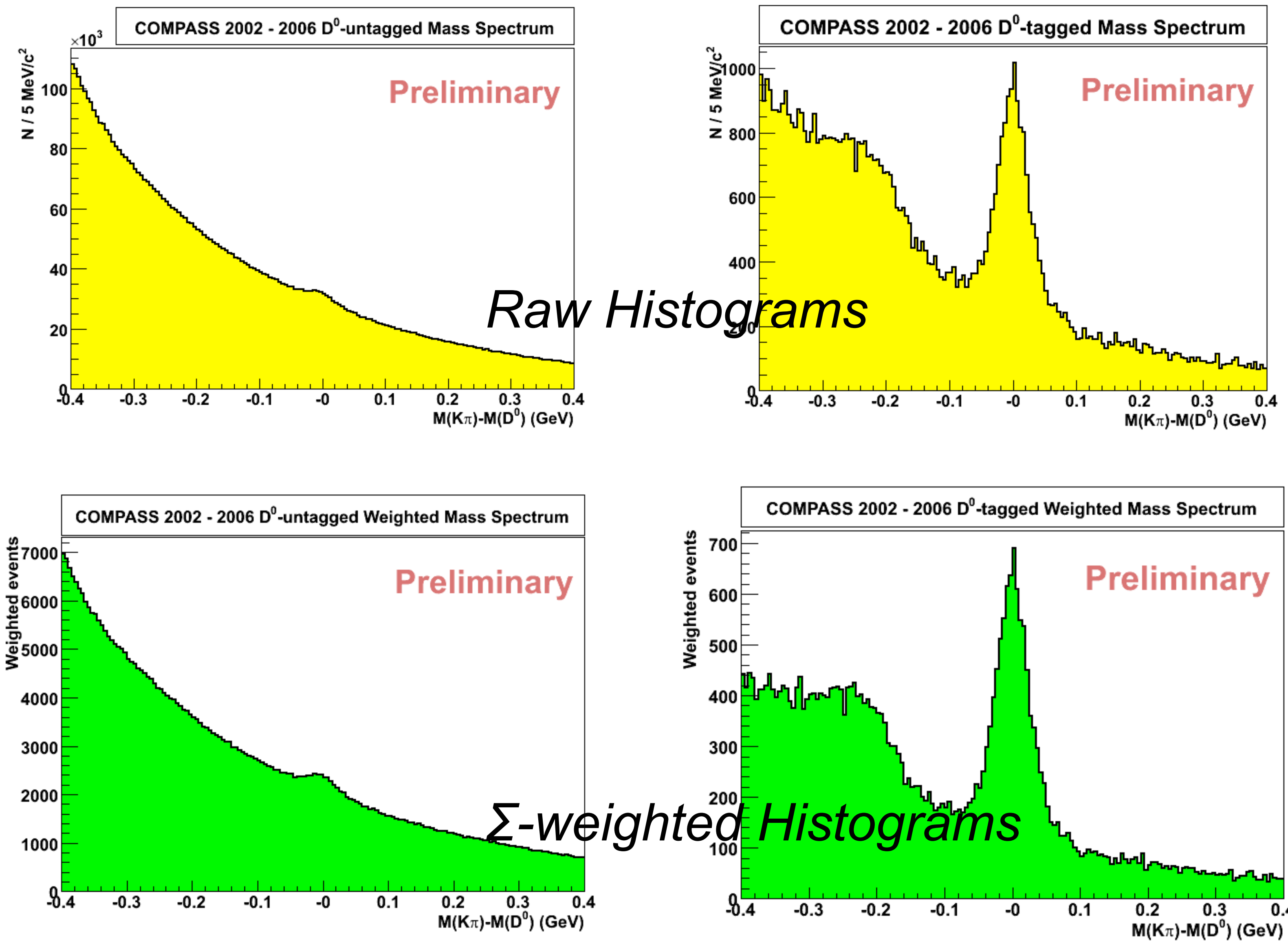
$$\chi^2 = (\vec{N} - \vec{f})^T \, Cov^{-1} (\vec{N} - \vec{f})$$

Validation of parameterization *(2006 example)*





Invariant mass of Kπ pairs - S/(S+B) weighting



$$A = \frac{\int \Delta G(x_g)(\Delta\hat{\sigma}^{LO} + \Delta\hat{\sigma}^{NLO}_{SV})ds_1 dt_1 + \int \Delta G(x'_g)\Delta\hat{\sigma}^{NLO}_{hard} ds_4 ds_1 dt_1}{\int G(x_g)(\hat{\sigma}^{LO} + \hat{\sigma}^{NLO}_{SV})ds_1 dt_1 + \int G(x'_g)\hat{\sigma}^{NLO}_{hard} ds_4 ds_1 dt_1}$$

$$\hat{\sigma}^{NLO}(t_1,s_1) = \hat{\sigma}^{LO} + \hat{\sigma}^{NLO}_{SV} + \int \hat{\sigma}^{NLO}_{hard} ds_4$$

$$\Delta\hat{\sigma}^{NLO}(t_1,s_1) = \Delta\hat{\sigma}^{LO} + \Delta\hat{\sigma}^{NLO}_{SV} + \int \Delta\hat{\sigma}^{NLO}_{hard} ds_4$$

$$A = \frac{\int \frac{\Delta G}{G} \frac{\Delta\hat{\sigma}^{NLO}(t_1,s_1)}{\hat{\sigma}^{NLO}(t_1,s_1)} G(x_g)\hat{\sigma}^{NLO}(t_1,s_1)dt_1 ds_1}{\int G(x_g)\hat{\sigma}^{NLO}(t_1,s_1)dt_1 ds_1}$$

$$A = \frac{\int \frac{\Delta G}{G} a^{NLO}_{LL} G(x_g)\hat{\sigma}^{NLO}(t_1,s_1)dt_1 ds_1}{\int G(x_g)\hat{\sigma}^{NLO}(t_1,s_1)dt_1 ds_1}$$

NLO - method 2
event is defined by s_1 and $t_1(u_1)$
s_1 define x_g

$$A=\frac{\int \Delta G(x_g)(\Delta\hat{\sigma}^{LO}+\Delta\hat{\sigma}^{NLO}_{SV})du_1dt_1+\int \Delta G(x'_g)\Delta\hat{\sigma}^{NLO}_{hard}ds_4du_1dt_1}{\int G(x_g)(\hat{\sigma}^{LO}+\hat{\sigma}^{NLO}_{SV})du_1dt_1+\int G(x'_g)\hat{\sigma}^{NLO}_{hard}ds_4du_1dt_1}$$

$$=\frac{\int \Delta G(x_g)\left[\Delta\hat{\sigma}^{LO}+\Delta\hat{\sigma}^{NLO}_{SV}+\int\frac{\Delta G(x'_g)}{\Delta G(x_g)}\Delta\hat{\sigma}^{NLO}_{hard}ds_4\right]du_1dt_1}{\int G(x_g)\left[\hat{\sigma}^{LO}+\hat{\sigma}^{NLO}_{SV}+\int\frac{G(x'_g)}{G(x_g)}\hat{\sigma}^{NLO}_{hard}ds_4\right]du_1dt_1}$$

$$\hat{\sigma}^{NLO}(t_1,u_1)=\hat{\sigma}^{LO}+\hat{\sigma}^{NLO}_{SV}+\int\frac{G(x'_g)}{G(x_g)}\hat{\sigma}^{NLO}_{hard}ds_4$$

$$\Delta\hat{\sigma}^{NLO}(t_1,u_1)=\Delta\hat{\sigma}^{LO}+\Delta\hat{\sigma}^{NLO}_{SV}+\int\frac{\Delta G(x'_g)}{\Delta G(x_g)}\Delta\hat{\sigma}^{NLO}_{hard}ds_4$$

$$A=\frac{\int\frac{\Delta G}{G}\frac{\Delta\hat{\sigma}^{NLO}(t_1,u_1)}{\hat{\sigma}^{NLO}(t_1,u_1)}G(x_g)\hat{\sigma}^{NLO}(t_1,u_1)du_1dt_1}{\int G(x_g)\hat{\sigma}^{NLO}(t_1,u_1)du_1dt_1}$$

$$A=\frac{\int\frac{\Delta G}{G}a^{NLO}_{LL}G(x_g)\hat{\sigma}^{NLO}(t_1,u_1)du_1dt_1}{\int G(x_g)\hat{\sigma}^{NLO}(t_1,u_1)du_1dt_1}$$

NLO - method 1
event is defined
by u_1 and t_1
$s_1^{el}=-u_1-t_1$ define x_g

$$2 \to 2 \qquad \Rightarrow \qquad g(k_1) + \gamma(k_2) \to c(p_1) + \bar{c}(p_2)$$

$$2 \to 3 \qquad \Rightarrow \qquad g(k_1) + \gamma(k_2) \to c(p_1) + \bar{c}(p_2) + g(k_3)$$

$$s_1 = (k_1 + k_2)^2 + Q^2 = 2k_1k_2$$

$$t_1 = (k_2 - p_2)^2 - m^2 = -2p_2k_2$$

$$u_1 = (k_1 - p_2)^2 - m^2 = -2p_2k_1$$

$$s_4 = (k_3 + p_1)^2 - m^2 = 2k_3p_1$$

$$x_g = \frac{s_1}{2Pq} = \frac{s_4 - t_1 - u_1}{2MEy}$$

$$2 \to 2 \qquad \Rightarrow \qquad s_1 + t_1 + u_1 = 0$$

$$2 \to 3 \qquad \Rightarrow \qquad s_1 + t_1 + u_1 = s_4$$

Asymmetries in bins in p_T and E of D^0

Table 2
The asymmetries $A^{\gamma N \to D^0 X}$ in bins of $p_T^{D^0}$ and E_{D^0} for the D^0 and D^* sample combined, together with the averages of several kinematic variables. Only the statistical errors are given. The relative systematic uncertainty is 20% which is 100% correlated between the bins.

Bin limits		$A^{\gamma N \to D^0 X}$	$\langle y \rangle$	$\langle Q^2 \rangle$ $(\mathrm{GeV}/c)^2$	$\langle p_T^D \rangle$ (GeV/c)	$\langle E_D \rangle$ (GeV)	$D(\langle X \rangle)$	$a_{LL}(\langle X \rangle)$
p_T^D (GeV/c)	E_D (GeV)							
0–0.3	0–30	-1.34 ± 0.85	0.47	0.50	0.19	24.8	0.57	0.37
0–0.3	30–50	-0.27 ± 0.52	0.58	0.75	0.20	39.2	0.70	0.48
0–0.3	> 50	-0.07 ± 0.66	0.67	1.06	0.20	60.0	0.80	0.61
0.3–0.7	0–30	-0.85 ± 0.51	0.47	0.47	0.50	25.1	0.56	0.26
0.3–0.7	30–50	0.09 ± 0.29	0.58	0.65	0.51	39.4	0.71	0.34
0.3–0.7	> 50	-0.20 ± 0.37	0.67	0.68	0.50	59.6	0.80	0.46
0.7–1	0–30	-0.47 ± 0.56	0.48	0.53	0.85	25.2	0.58	0.13
0.7–1	30–50	-0.49 ± 0.32	0.58	0.66	0.85	39.1	0.70	0.17
0.7–1	> 50	1.23 ± 0.43	0.68	0.73	0.84	59.4	0.81	0.26
1–1.5	0–30	-0.87 ± 0.48	0.50	0.49	1.21	25.7	0.60	0.01
1–1.5	30–50	-0.24 ± 0.25	0.60	0.62	1.22	39.5	0.73	0.00
1–1.5	> 50	-0.18 ± 0.34	0.69	0.77	1.22	59.3	0.83	0.04
> 1.5	0–30	0.83 ± 0.71	0.52	0.51	1.77	26.2	0.63	−0.13
> 1.5	30-50	0.18 ± 0.28	0.61	0.68	1.87	40.0	0.74	−0.20
> 1.5	> 50	0.44 ± 0.33	0.71	0.86	1.94	59.9	0.84	−0.24

weighted!

$$w = f\, P_B \frac{S}{S+B} D$$

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