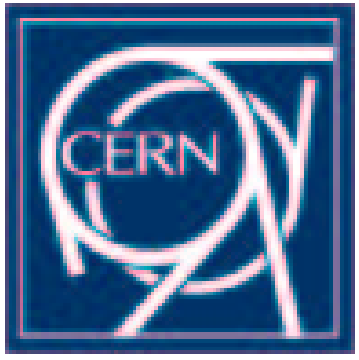
Spin Physics with COMPASS

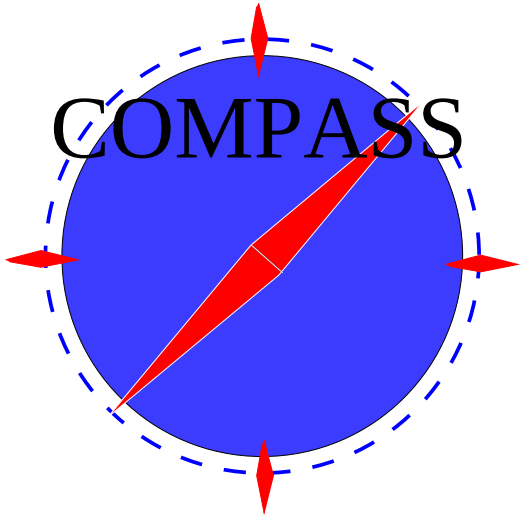
Jörg Pretz

Physikalisches Institut, Universität Bonn & CERN

on behalf of the

COMPASS collaboration





COMPASS

CO mmon

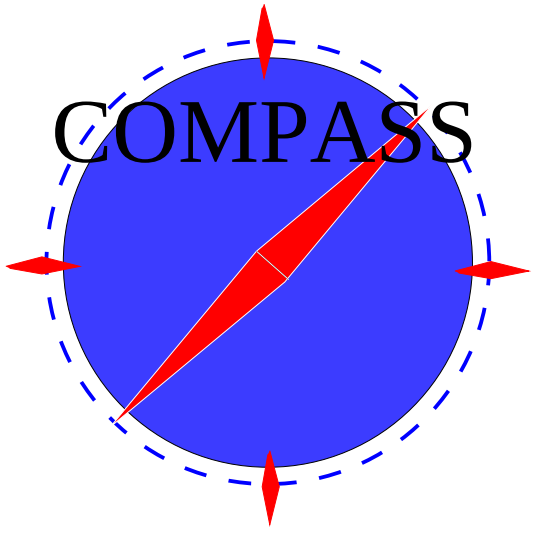
Muon and

Proton

Apparatus for

Structure and

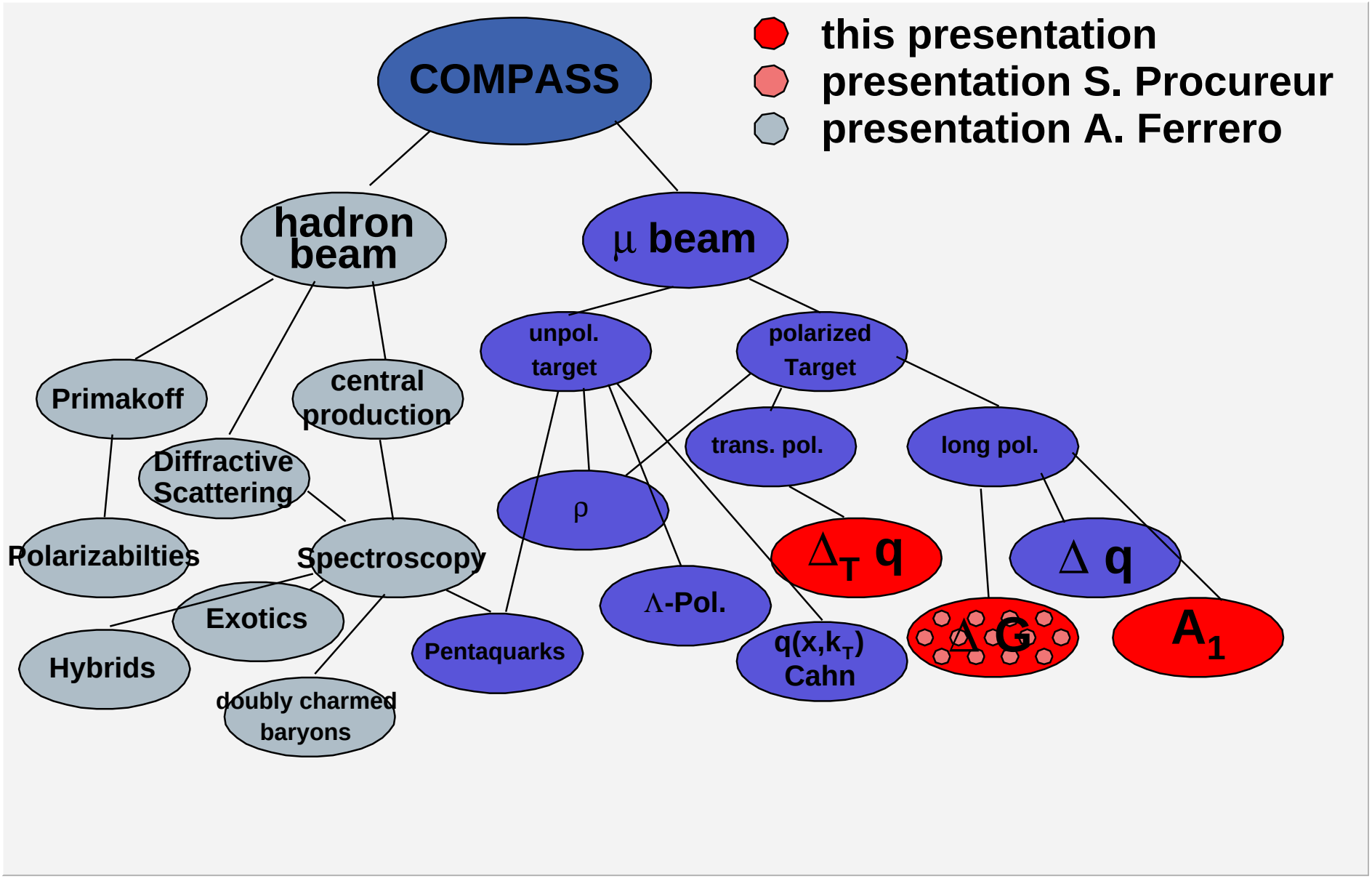
Spectroscopy



≈ 200 physicists
≈ 30 institutes,

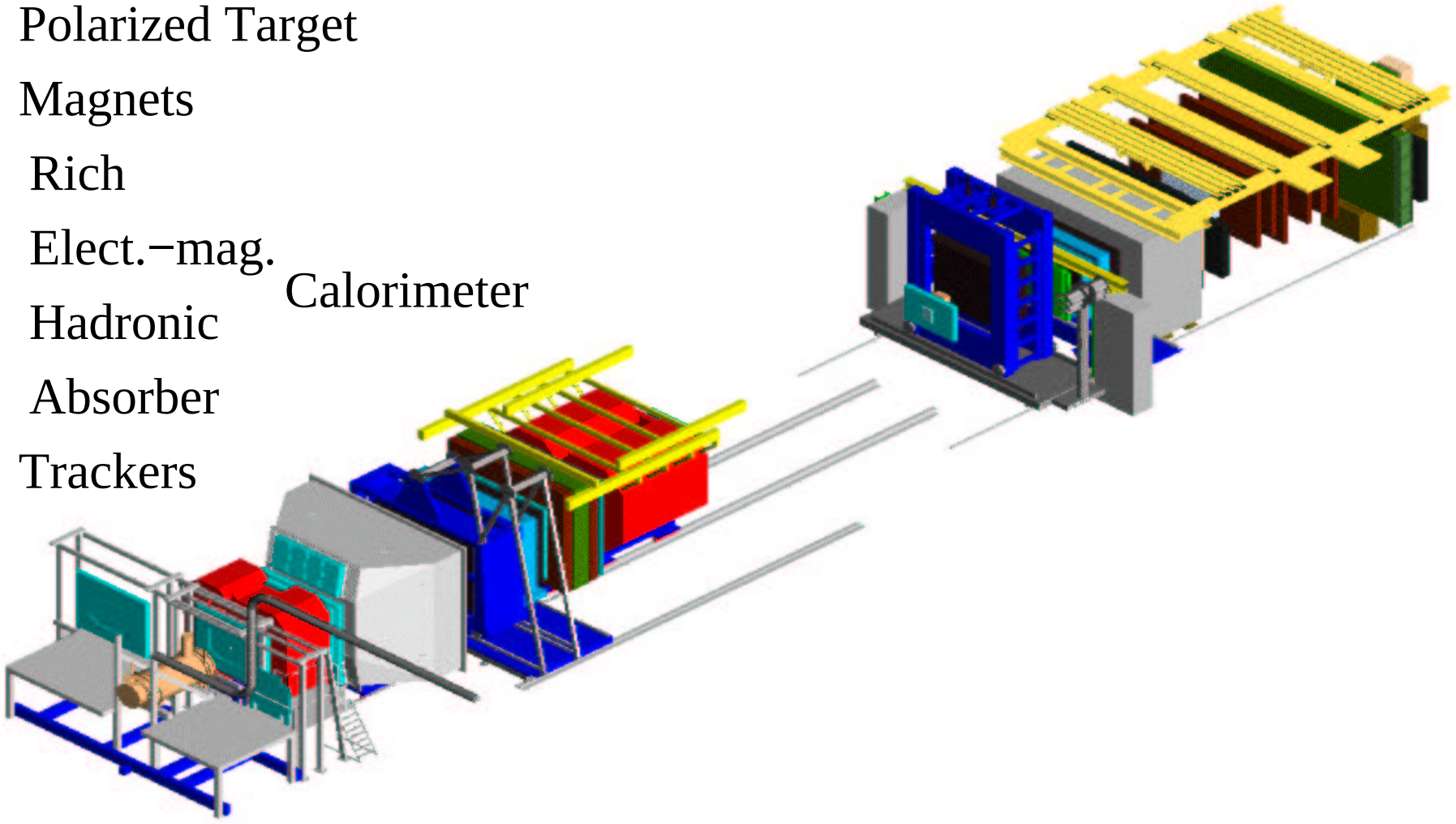
at CERN SPS

Physics Goals



The COMPASS Experiment

- Polarized Target
- Magnets
- Rich
- Elect.−mag. Calorimeter
- Hadronic
- Absorber
- Trackers

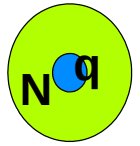


Parameters of Experiment

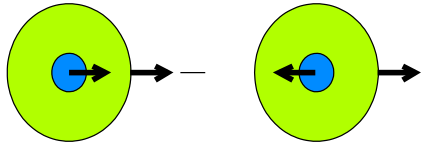
Spectrometer:	Two stages 1 GeV $< p <$ 200 GeV tracking: Scifis, GEMs , Micromegas, Straws particle id.: K, π separation $9 < p < 60$ GeV with RICH ECAL,HCAL,μFilter
Beam:	160 GeV μ , $2 \cdot 10^8/5$s, Pol = –0.76 $\pm$ 0.04 190 GeV π , $5 \cdot 10^6/5$s
pol. Target:	2 $\times$ 65 cm cells, oppositely polarized ^{6}LiD, Pol $\approx$ 0.5, DNP

Parton description of Nucleon

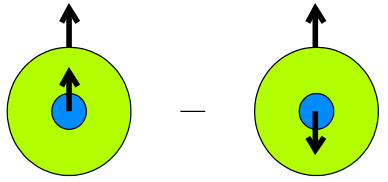
$f(x), f = u, d, s, \bar{u}, \bar{d}, \bar{s}, G$



$\Delta f(x)$ (helicity)



$\Delta_T f(x)$ (transversity)

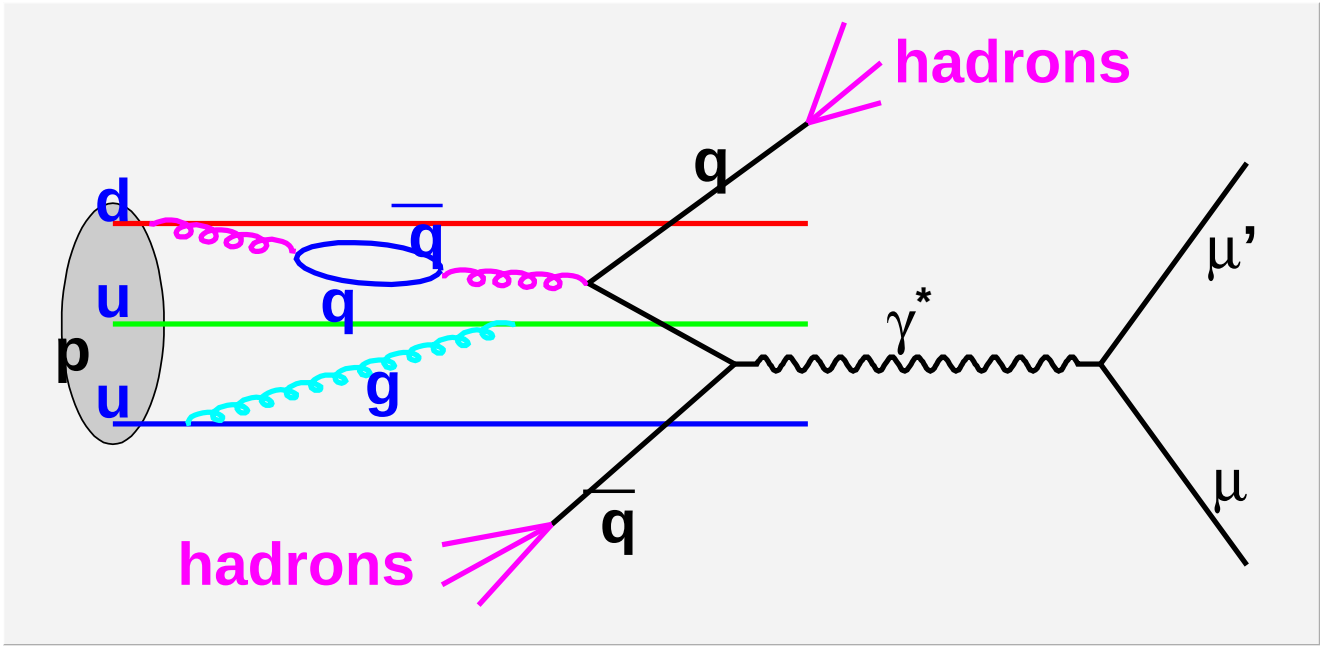


- Spin Puzzle:
  $\Delta\Sigma = \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s} \approx 0.2 - 0.3 \ll 1$
  Helicity contribution of quarks is small!
- ΔG ???
- $\Delta_T f(x)$ as important as $\Delta f(x)$, less well known, because more difficult to access.

How to measure ΔG?

Use hadronic final state in DIS to tag gluon!

$\vec{\mu} + \vec{N} \rightarrow \mu' +$ hadrons $+ X$



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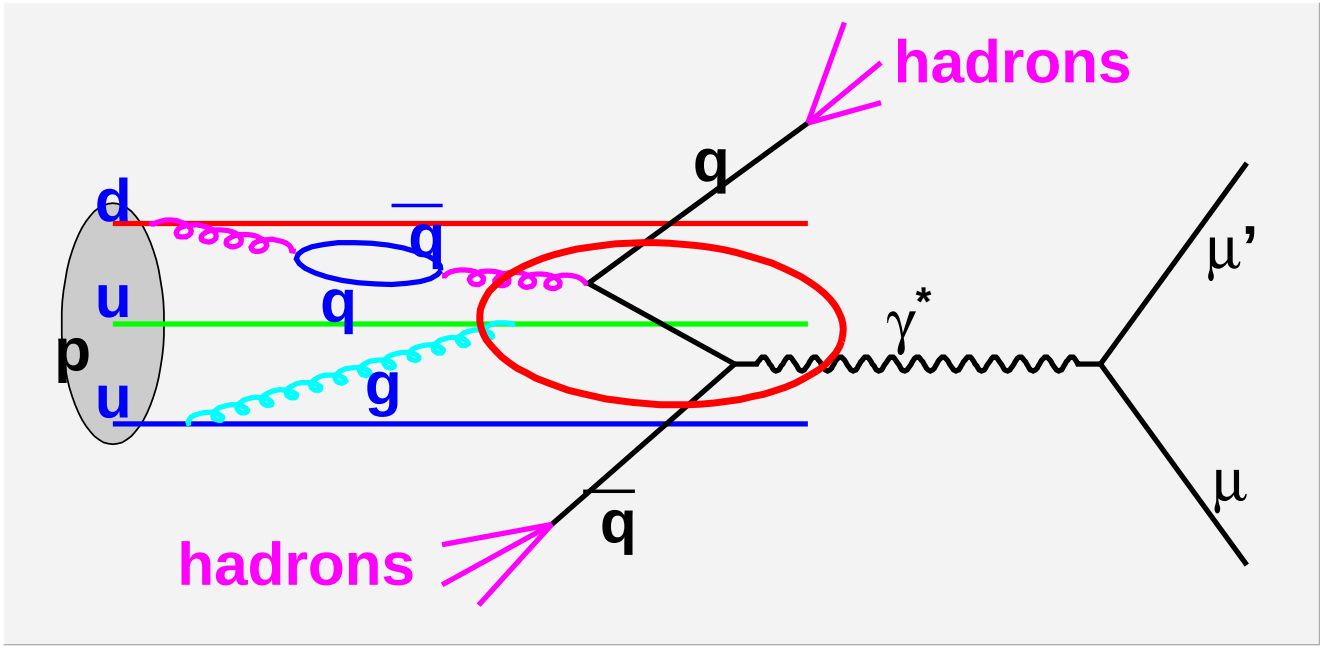
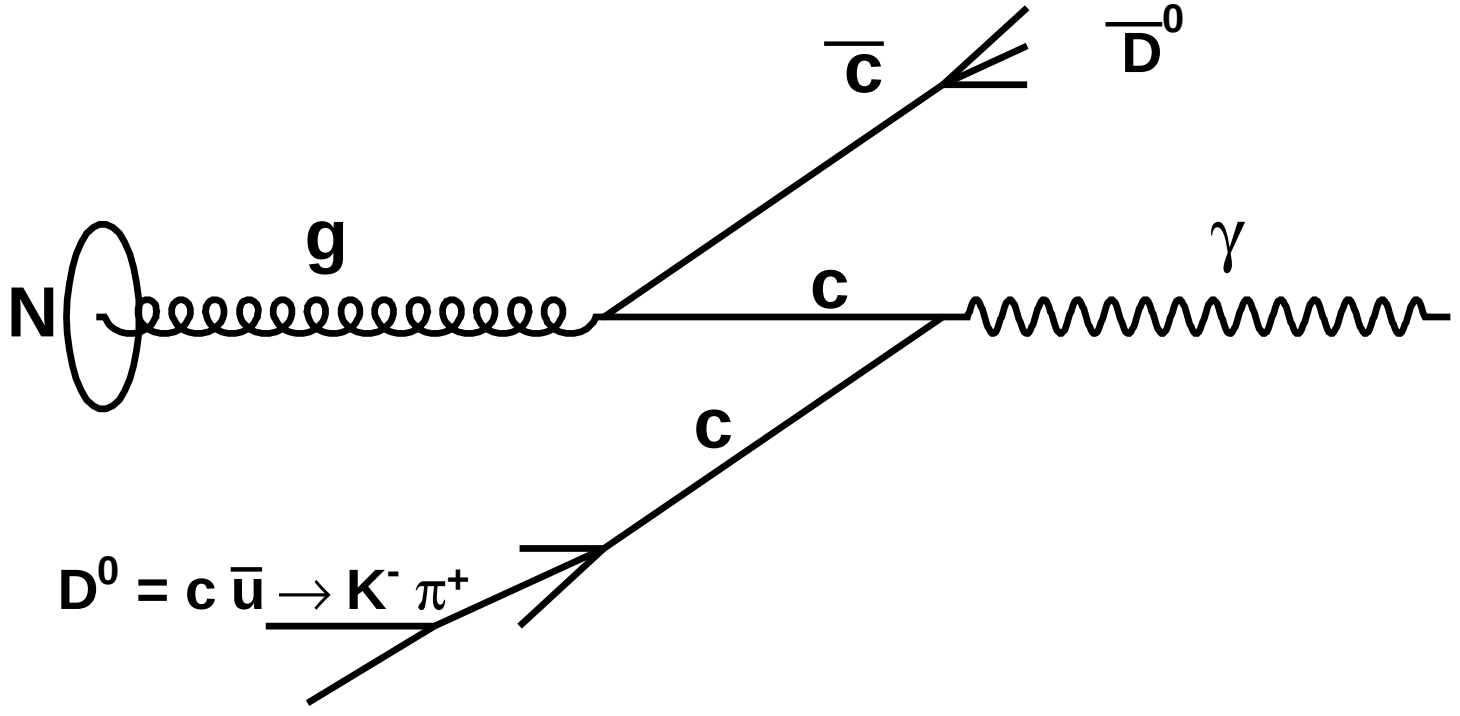


How to tag sub-process

$\gamma^* g \rightarrow q\bar{q}$?

How to tag $\gamma^* g \to q\bar{q}$?

	advantage	disadvantage
open charm	clean tag	low statistics
high p_T hadron	higher statistics	background processes



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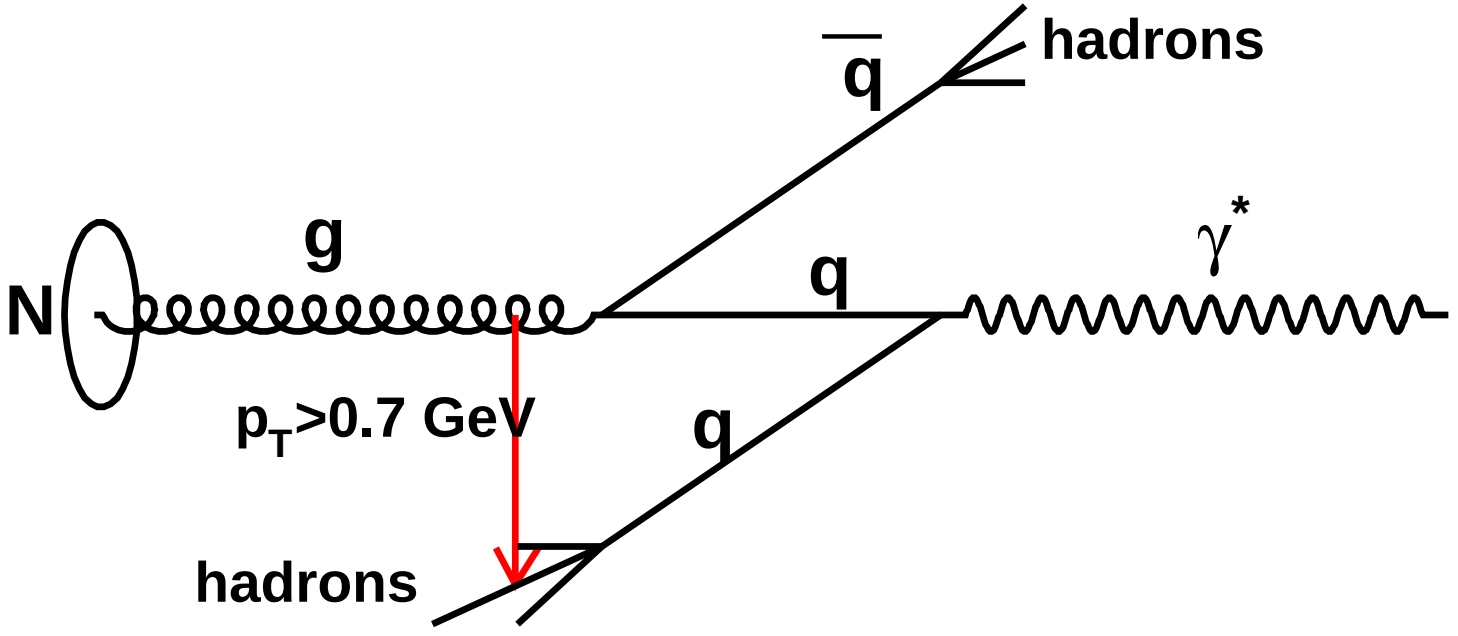

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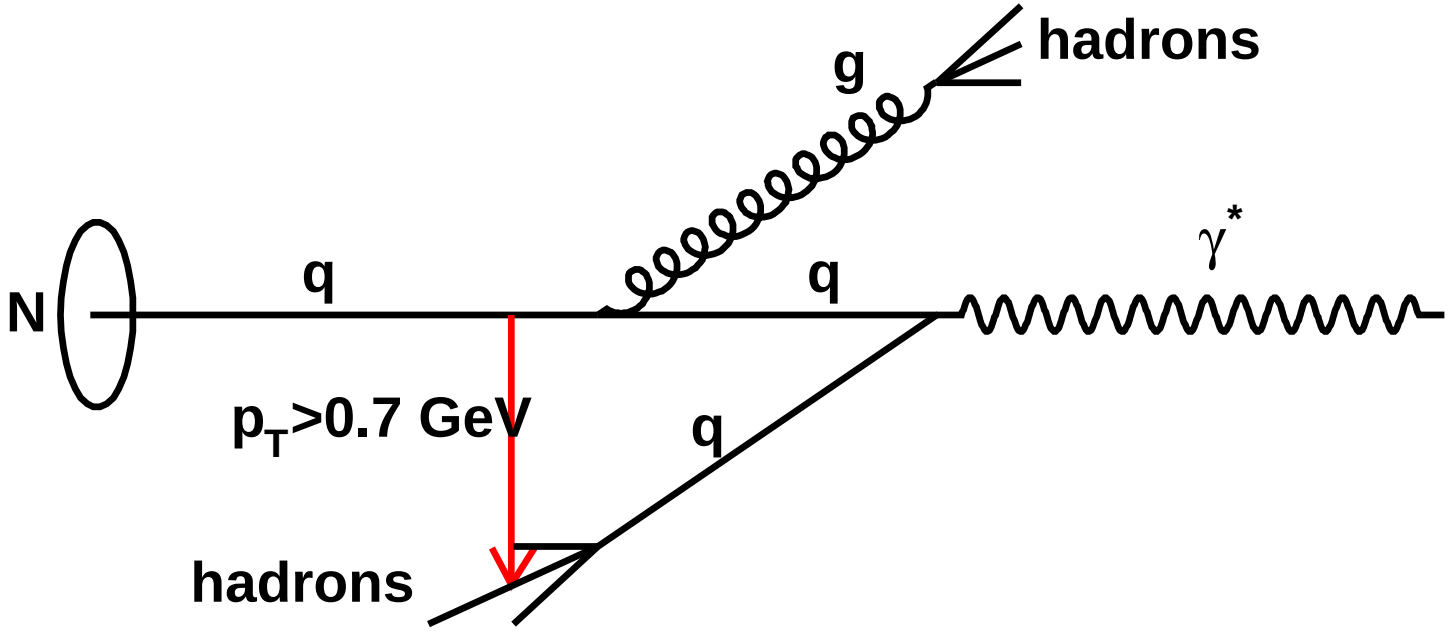

Compton process one of background processes

Tagging $\gamma^* g \to q\bar{q}$ with high p_T hadrons

Several possibilities:

method	advantage	disadvantage
hadron pairs $Q^2 > 1\text{GeV}^2$	only few background processes (LEPTO)	low statistics
hadron pairs $Q^2 < 1\text{GeV}^2$	resolved photon as background process (PYTHIA)	10 $\times$ statistics
single hadrons	comparison with theoretical calculation (Schäfer et al.)	tagging of $\gamma^* g \to q\bar{q}$ less clean

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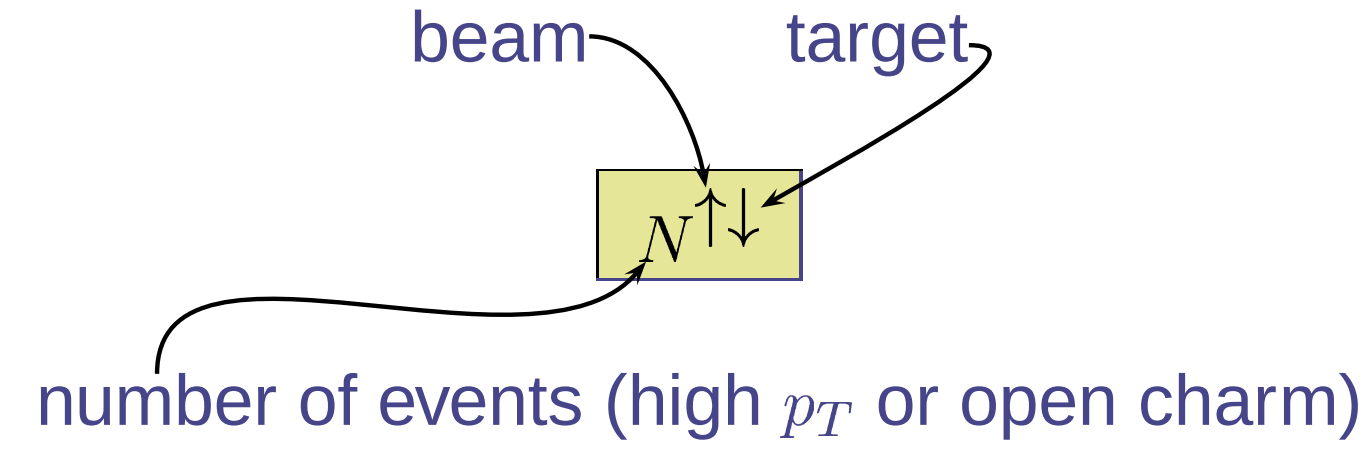
Results will be shown

More details in S. Procureur's presentation

- To tag gluon look at
  - charmed hadrons
  - hadrons with large transverse momentum
- To learn something about spin measure double spin asymmetries

$$A^{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} \propto \frac{\Delta G}{G}$$



Asymmetries $\rightarrow \Delta G/G$

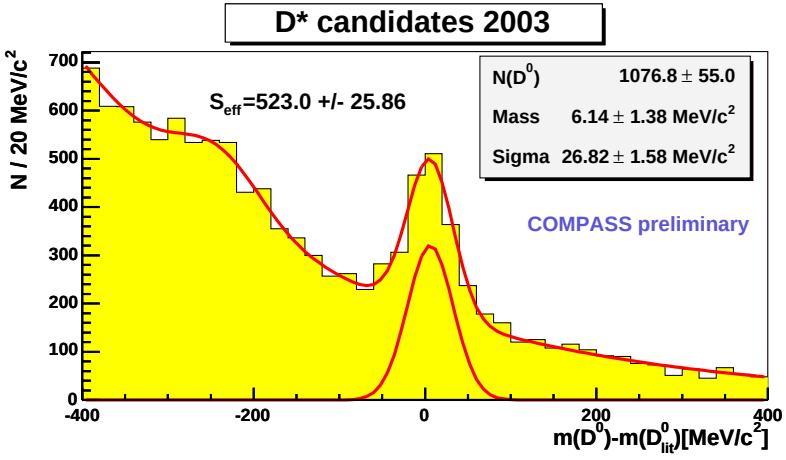
$$A^{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = P_B \, f \, P_T \, a_{LL} \frac{\sigma_{PGF}}{\sigma_{tot}} \frac{\Delta G}{G} + A^{bgd}$$

	high p_T	opencharm
$P_B \approx 0.8$	beam polarization	
$f \approx 0.4$	dilution factor (^{6}LiD target)	
$P_T \approx 0.5$	target polarization	
a_{LL}	asymmetry of partonic process	
	≈ -0.4	-0.5 to 0.5
$\frac{\sigma_{PGF}}{\sigma_{tot}}$	fraction of photon-gluon fusion process	
	0.3	0.5(D^*) 0.1 (D^0)
	LEPTO/PYTHIA MC	combinatorial background
A^{bgd}	background asymmetry	

For $\frac{\Delta G}{G} = 0.5 \rightarrow A^{raw} \approx$few %

$\Delta G/G$ via Open Charm

$$D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+\pi^+$$



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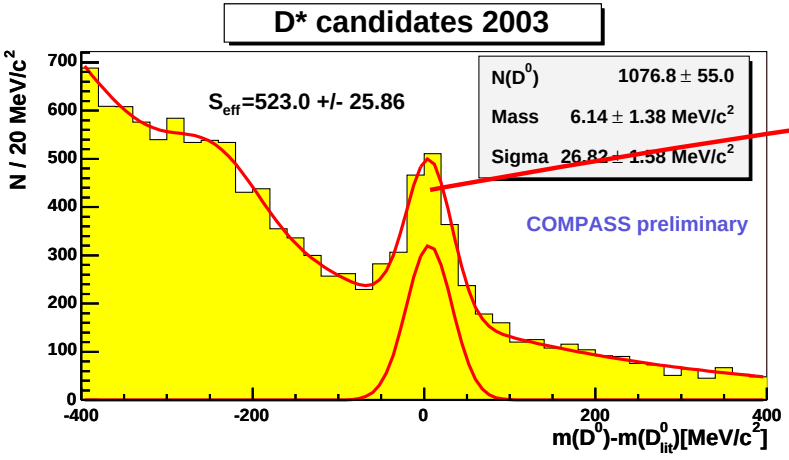

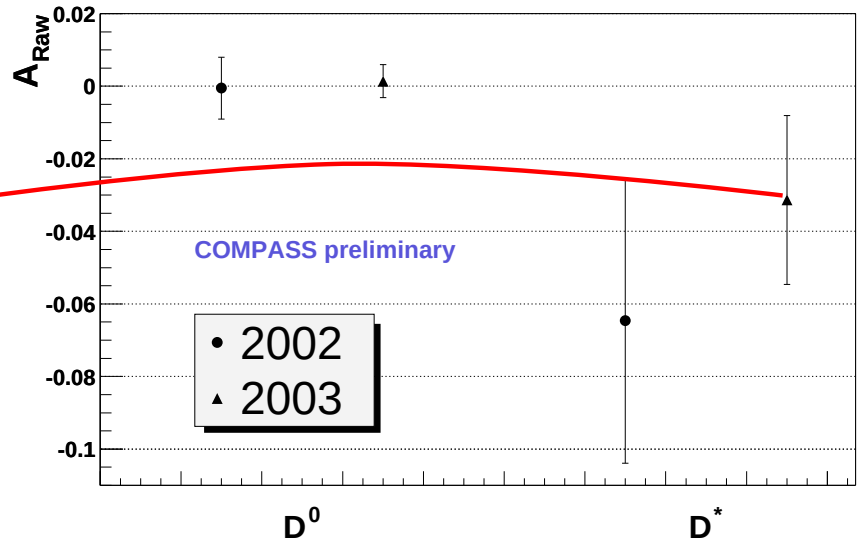

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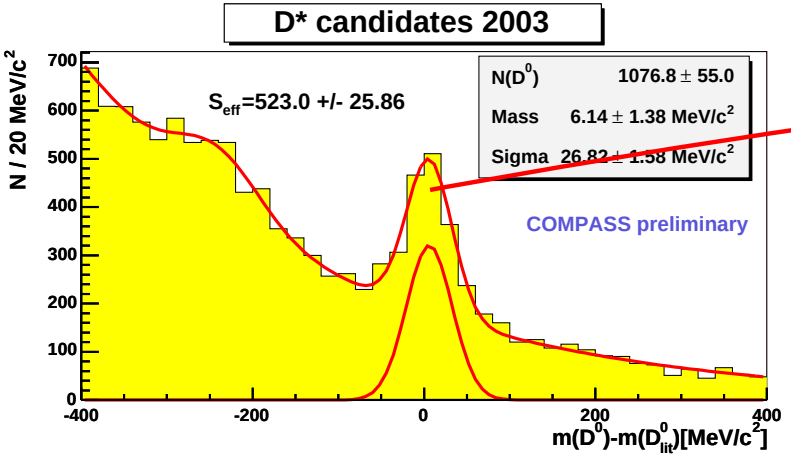

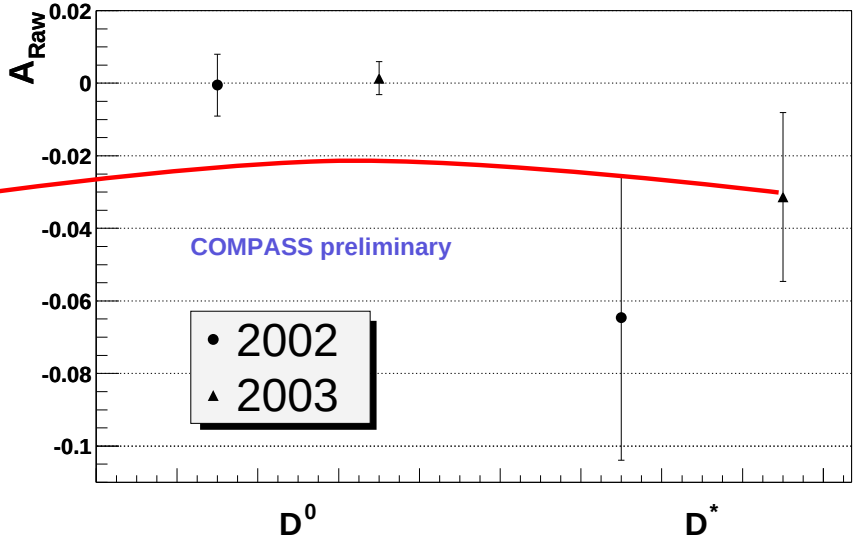

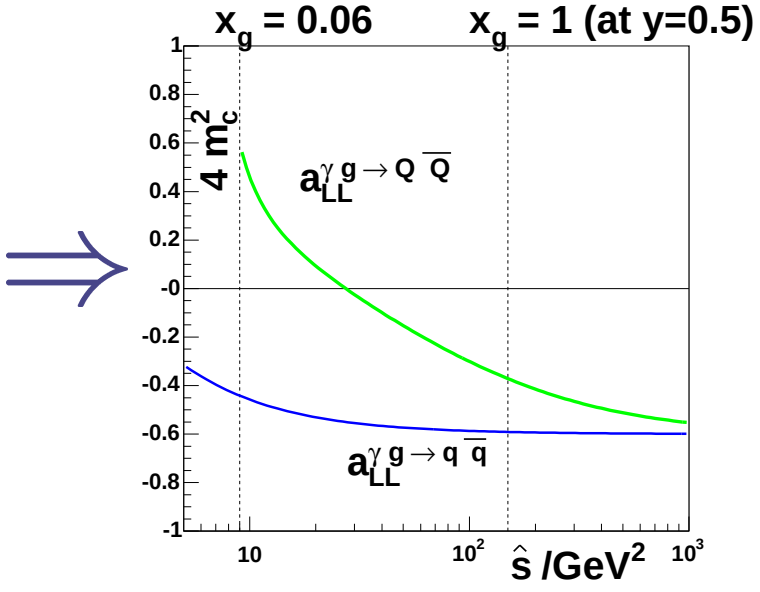

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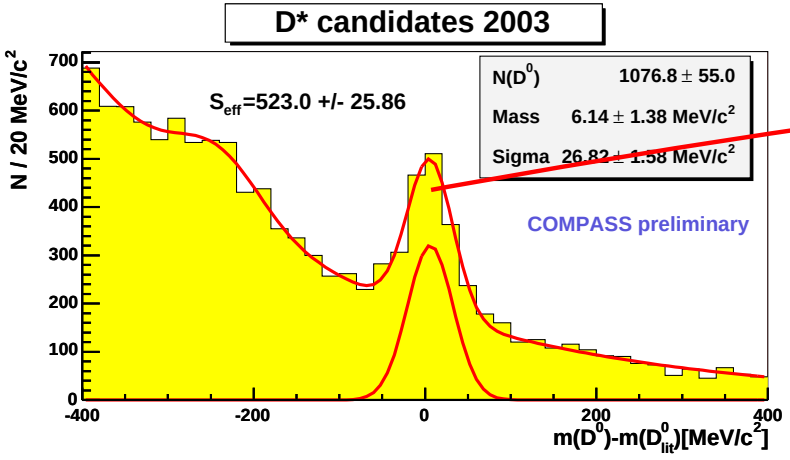

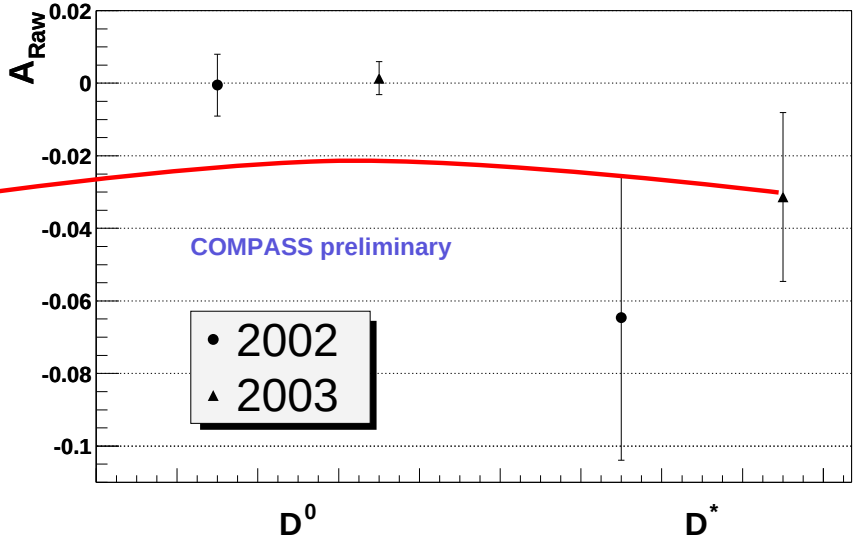

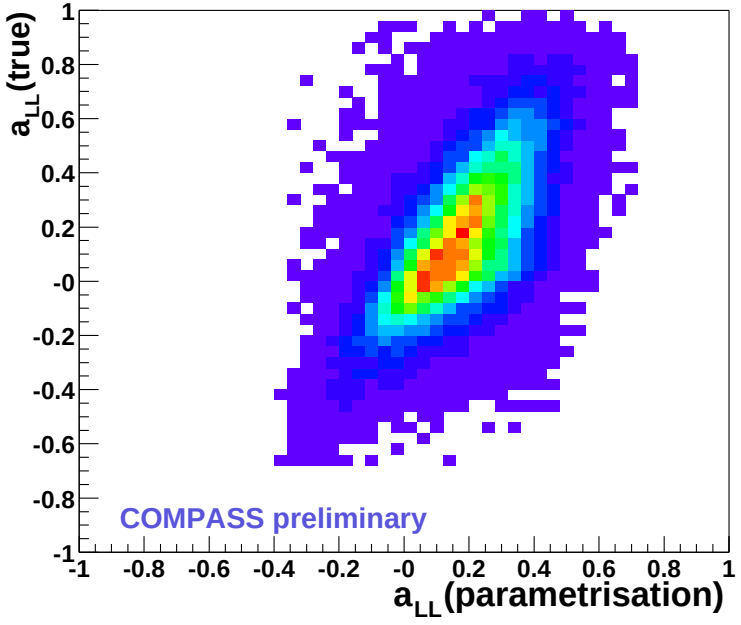

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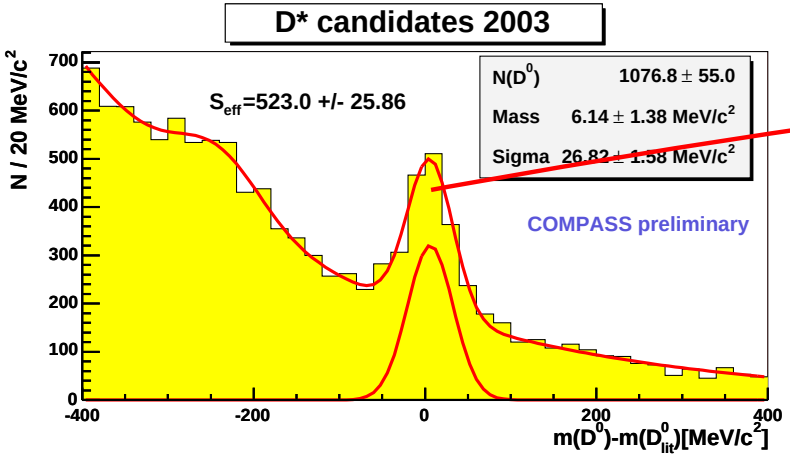
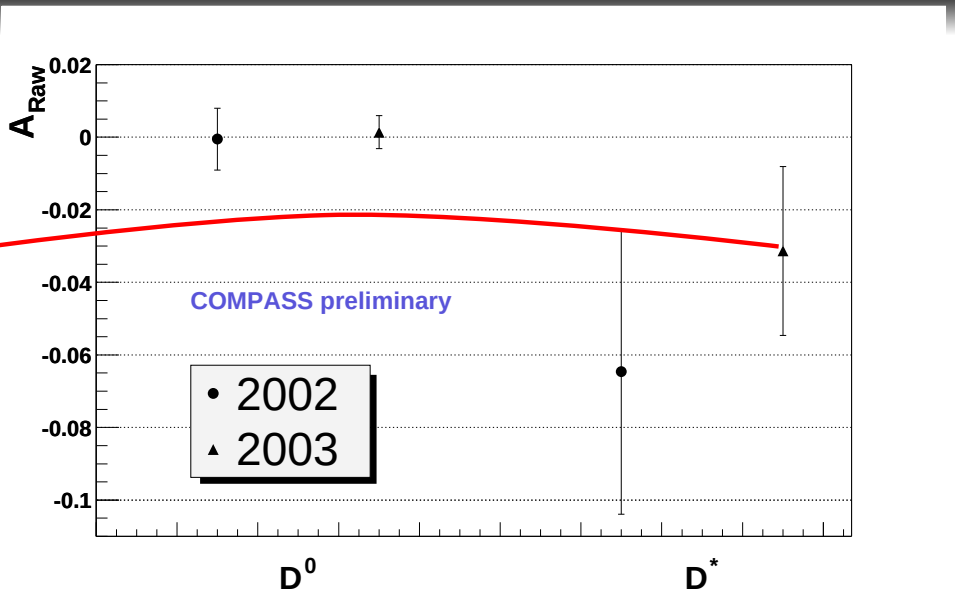
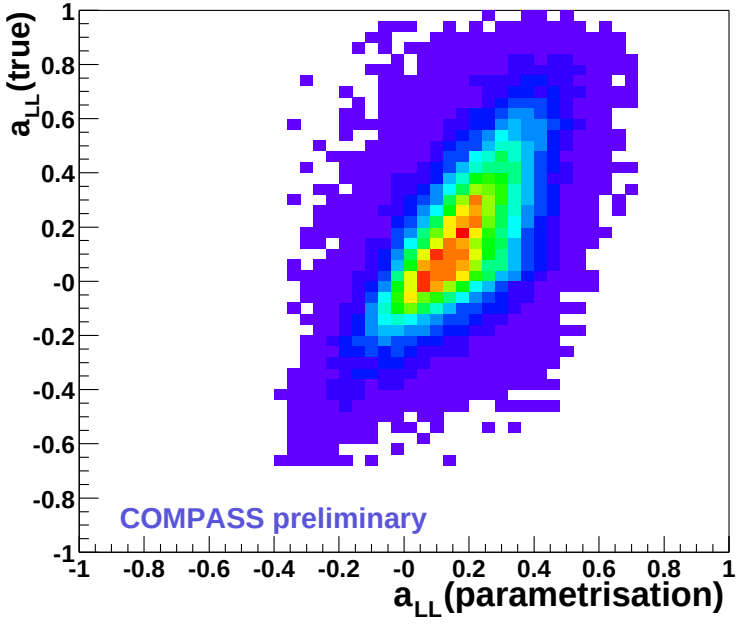
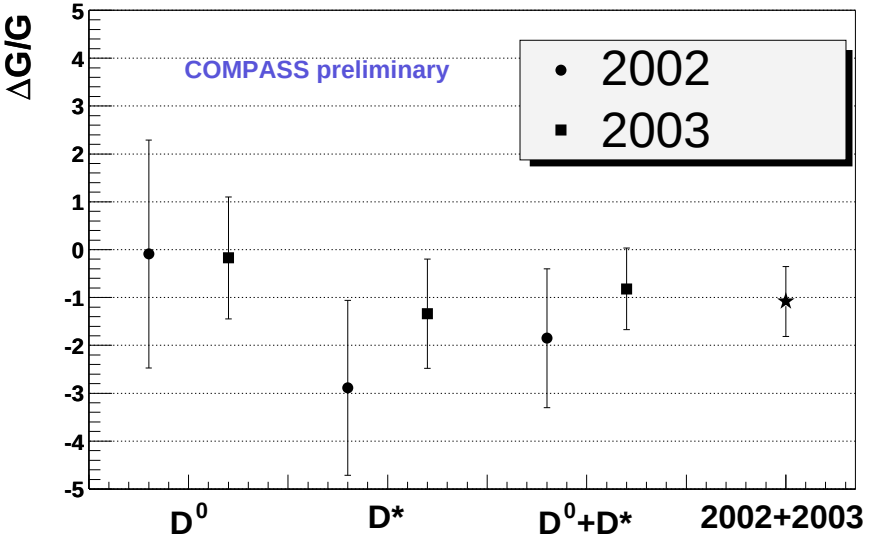
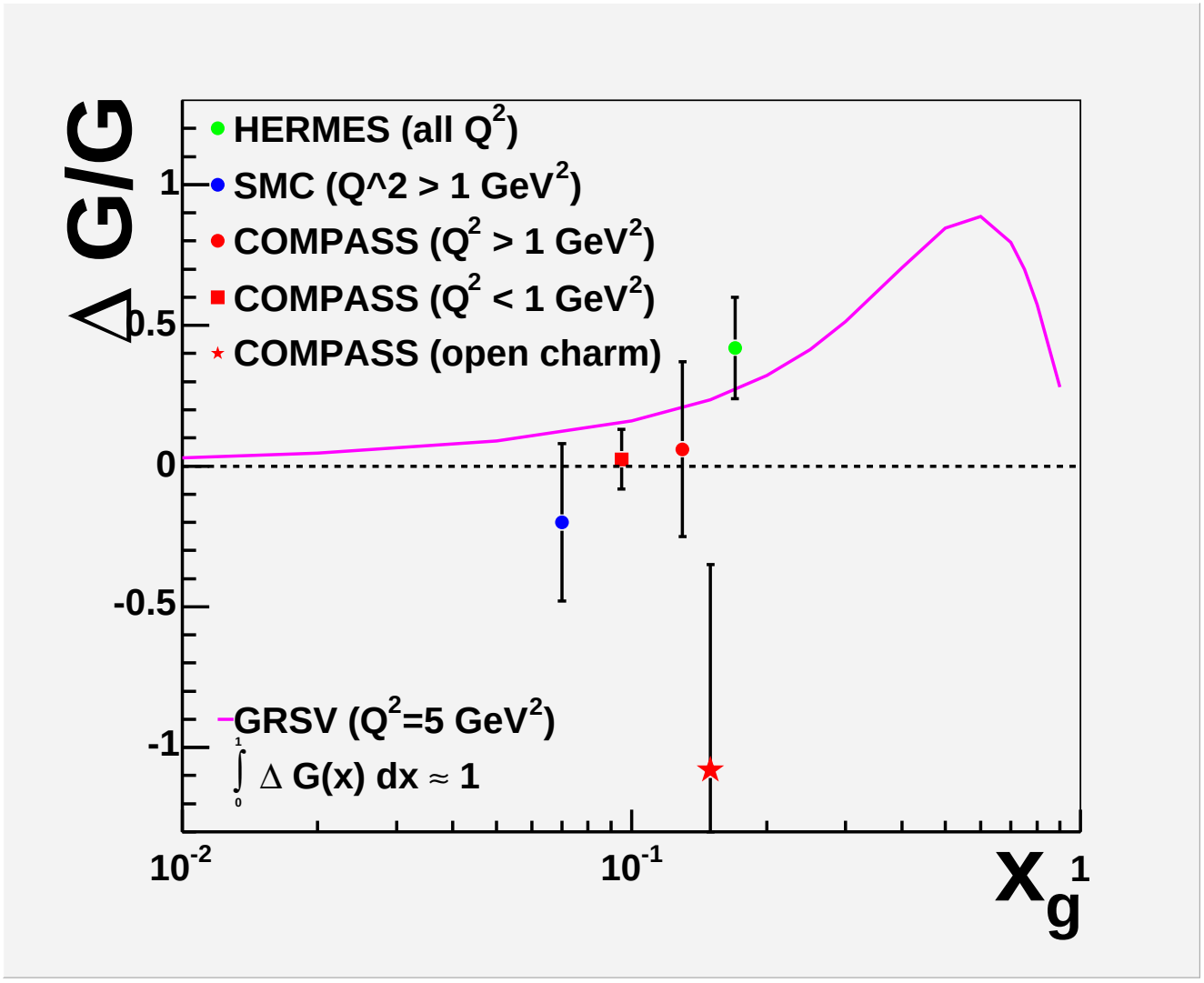






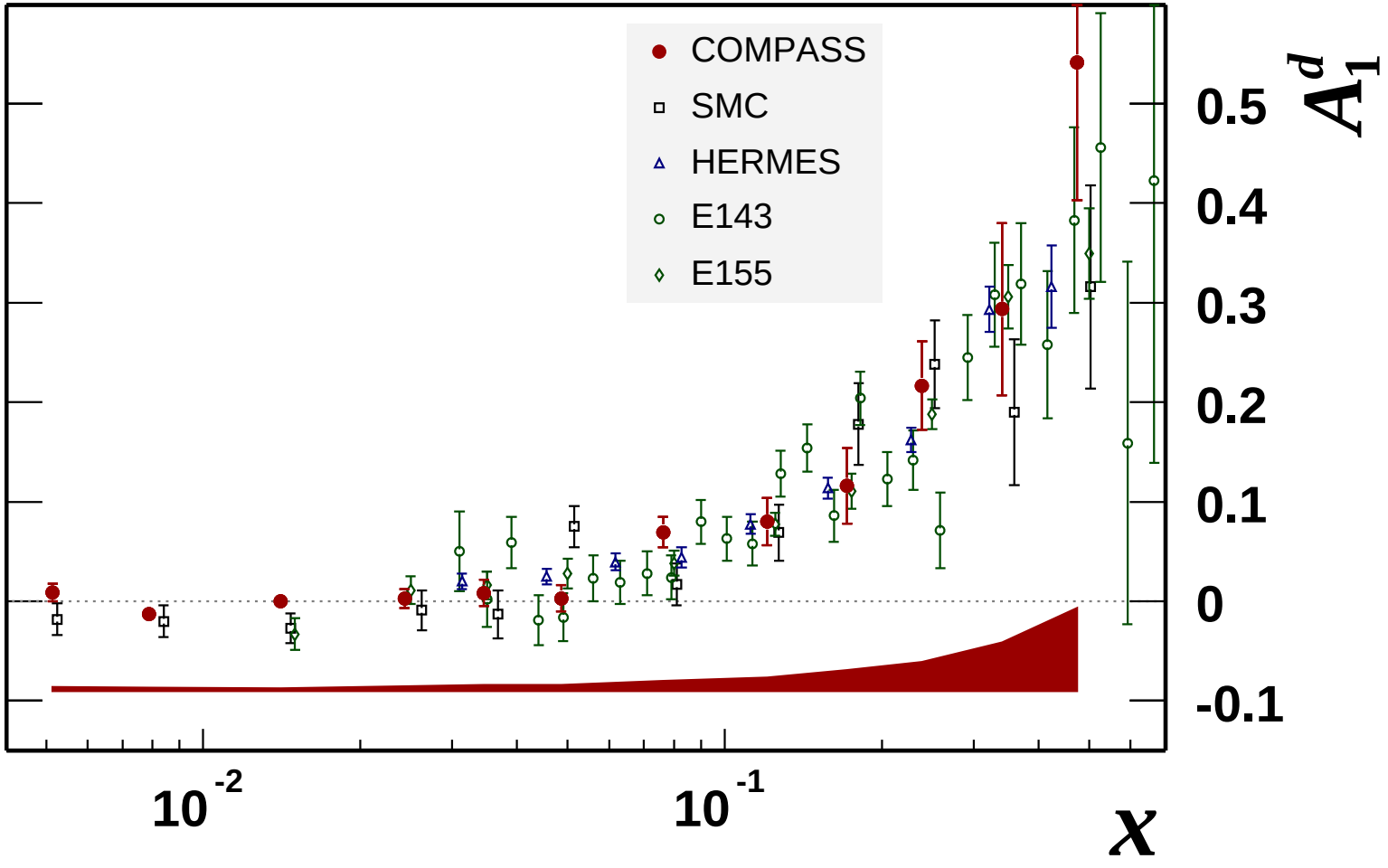


$\Delta G/G$



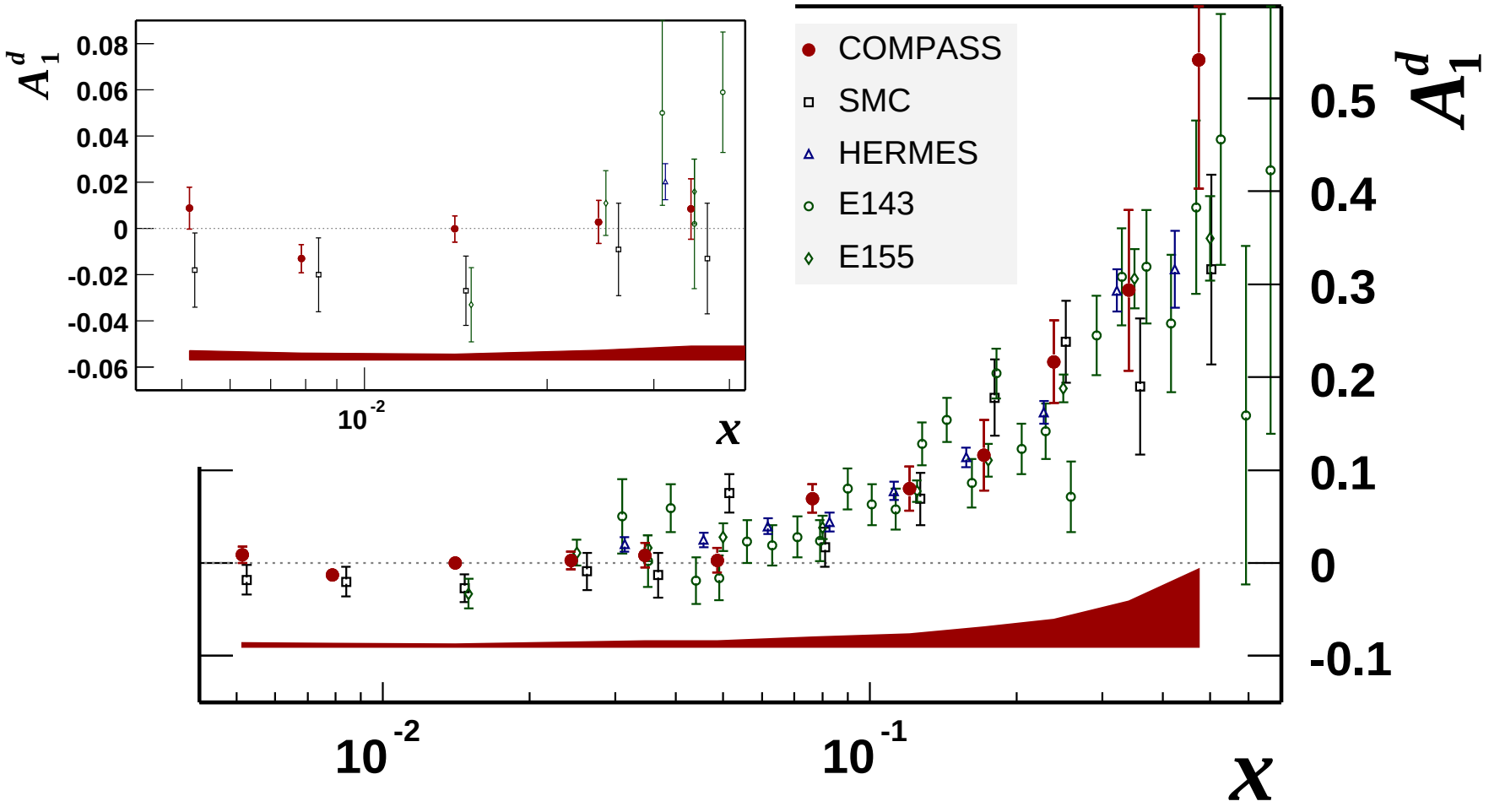
- Values of $\Delta G > 2$ are disfavored
- $\Delta G(x \approx 0.1)$ is small

Inclusive asymmetry A_1^d $(\vec{\mu} + \vec{N} \to \mu' + X)$



- Good agreement at large x

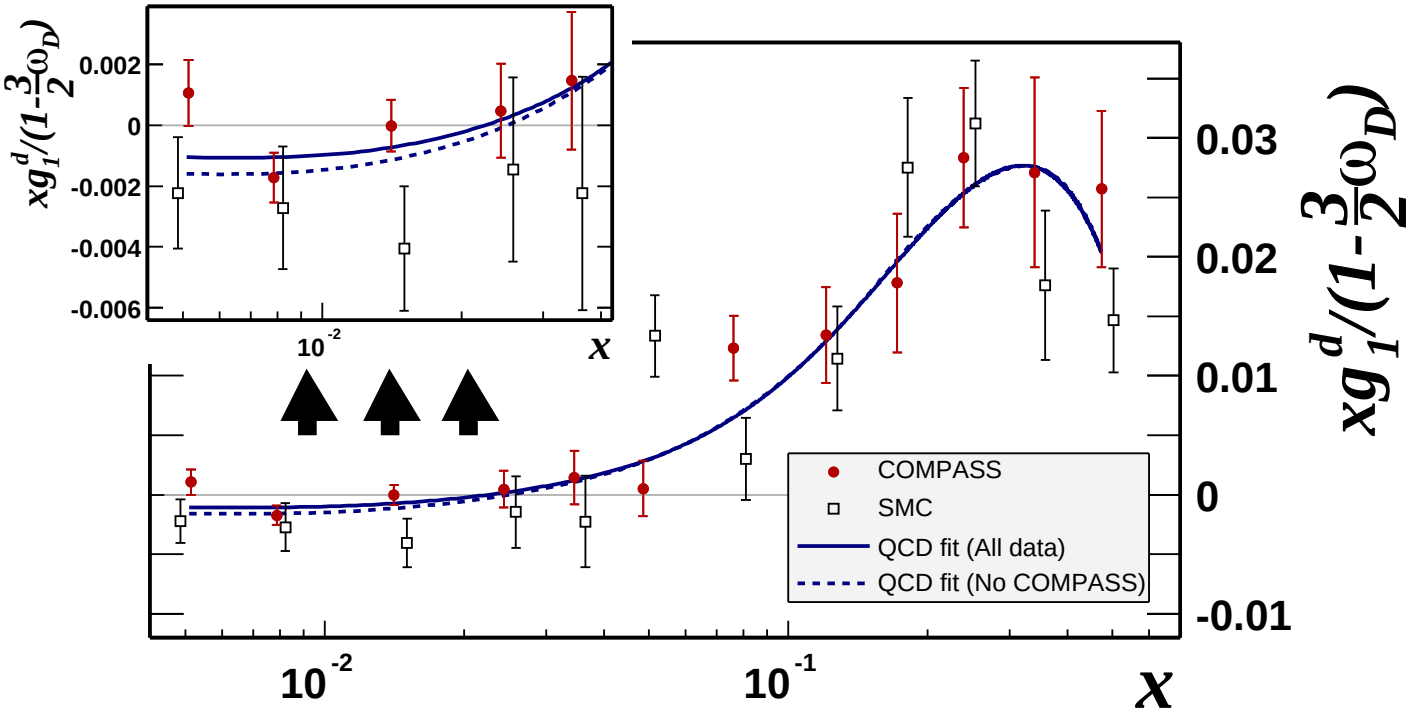
Inclusive asymmetry $A_1^d\ (\vec{\mu} + \vec{N} \to \mu' + X)$



- Factor 2 improvement at low x.
- Good agreement at large x

QCD Fits

- structure function $g_1^d (\approx A_1^d \times F_1^d)$:



$$\int_0^1 \Delta\Sigma(x)dx = 0.237 + 0.024 - 0.029 \quad \text{for whole data set}$$

$$= 0.202 + 0.042 - 0.077 \quad \text{without COMPASS}$$

Transversity distributions

$\Delta_T q(x)$ complete description of the nucleon
(at leading twist, k_T integrated)

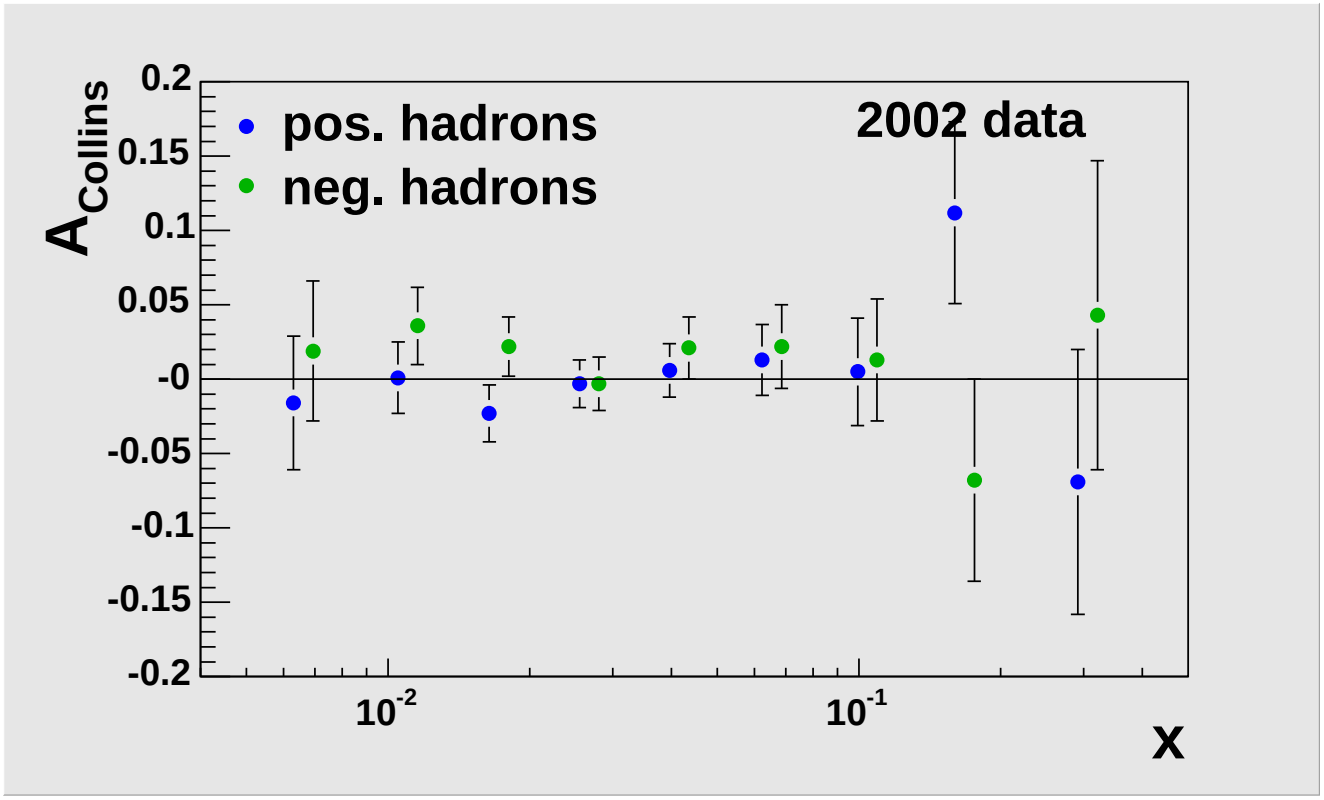
Asymmetries $\propto \Delta_T q(x) \times$ analyzing power

To measure transverse polarization of quarks different "polarimeters" proposed:

Collins Asymmetry	$\propto$	$\Delta_T q(x)$	$\Delta_T^0 D_q^h(z, \lvert p_T^h \rvert)$	✓
2 hadron correlation	$\propto$	$\Delta_T q(x)$	$H_q^{\angle h}(z, M_h)$	✓
Λ - Polarization	$\propto$	$\Delta_T q(x)$	$\Delta D_q^{\Lambda}(z)$	(in progress)

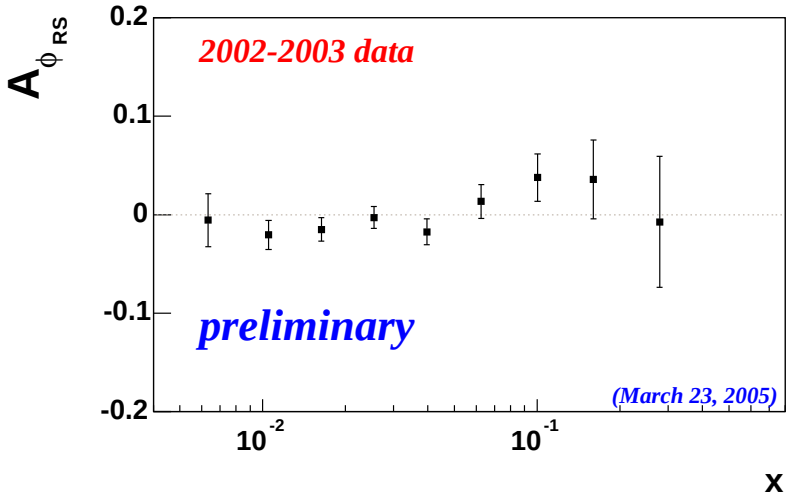
Analyzing power is different for different processes and even not known $\rightarrow$ important to try different methods.

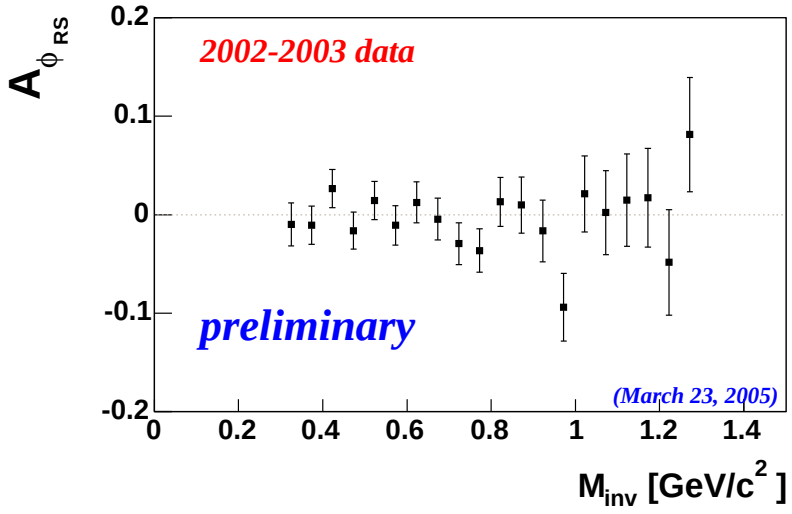
Transversity: 1 Hadron



$$A_{Collins} \propto \Delta_T q(x) \Delta_T^0 D_q^h(z, |p_T^h|)$$

Transversity: 2 Hadrons





$$A_{\Phi_{RS}} \propto \Delta_T q(x) H_q^{\angle h}(z, M_h)$$

- No sign of transversity observed
- either $\Delta_T q(x)$ or $\Delta_T^0 D_q^h, H_q^{\angle h}$ small

Summary

- COMPASS produced first results on $\frac{\Delta G}{G}$ from 2002 and 2003 data
- Several channels are followed to extract $\frac{\Delta G}{G}$
  - hadrons with large p_T,
  - open charm
- $\Delta G(x \approx 0.1)$ small
- first results on transversity consistent with 0
- 2004 data still being analyzed
- 2005 dedicated to analysis and spectrometer upgrade (Target, RICH)
- resume data taking in 2006 with muon beam
- 2007 hadron beam

SPARE

Spectroscopy:

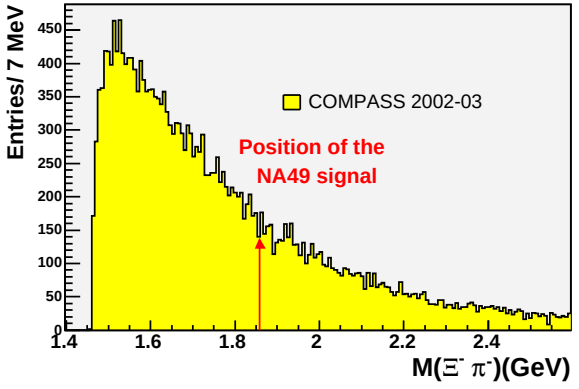
Search for pentaquark candidate $\Phi(1860)$ (was Ξ^{--}) in

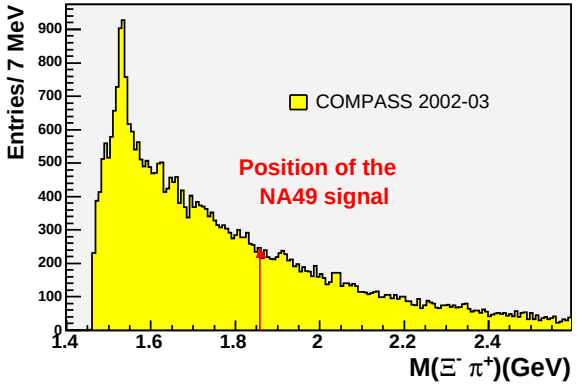
$$\mu + N \to \Xi^{--} + X$$

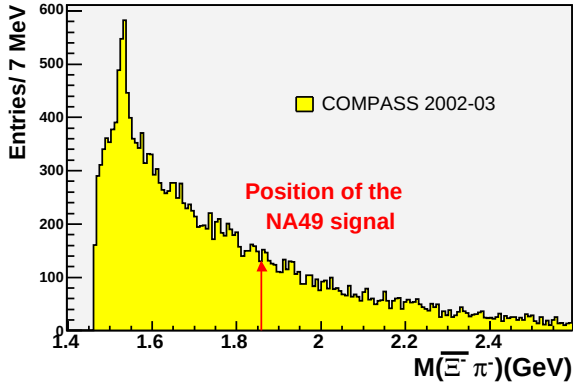
$$\Xi^{--} \to \Xi^{-}\pi^{-}$$

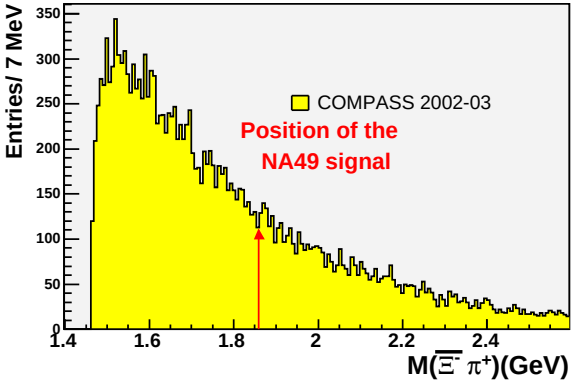
$$\Xi^{-} \to \Lambda\pi^{-}$$

$$\Lambda \to p\pi^{-}$$



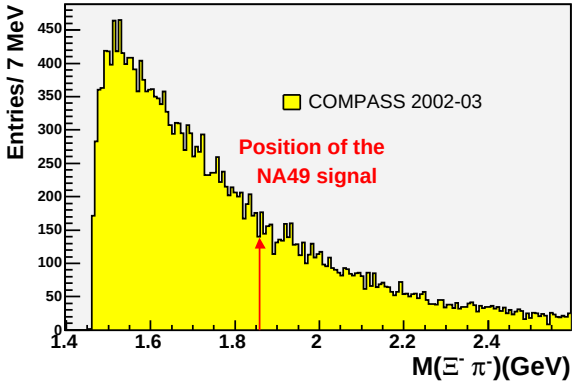


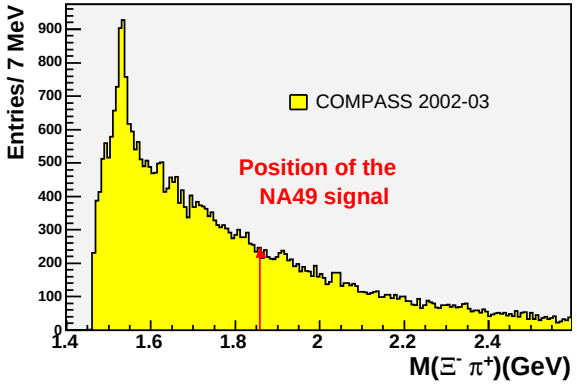


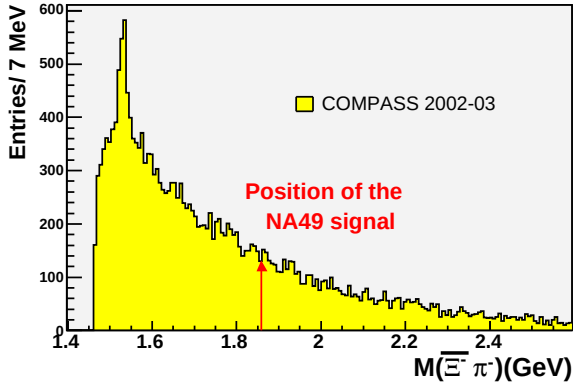


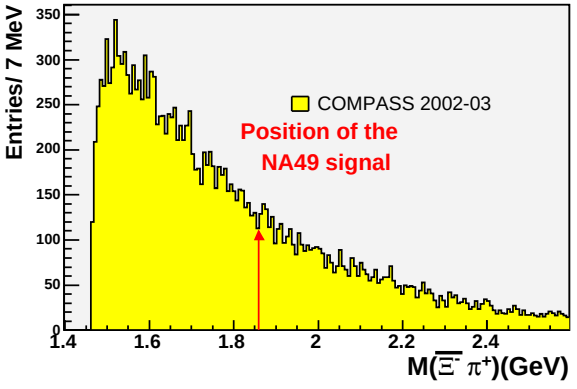
Spectroscopy:

- Assuming the same $\Xi(1869)^{--}/\Xi(1320)^{-}$ as NA49 COMPASS should have observed ≈ 400 $\Xi(1869)^{--}$
- Negative signal (< 80 at 99% CL)



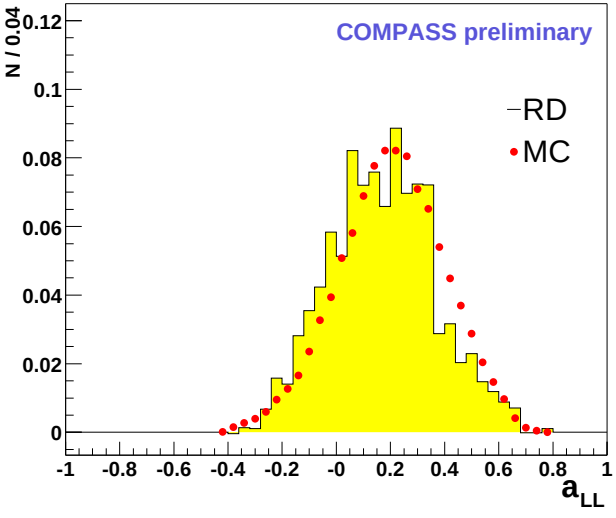


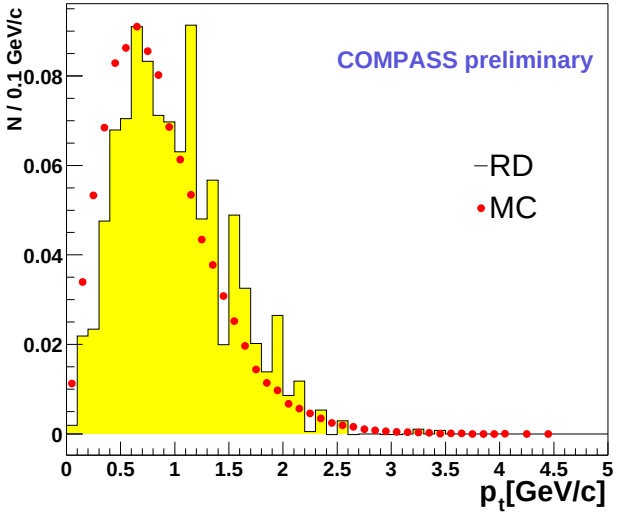


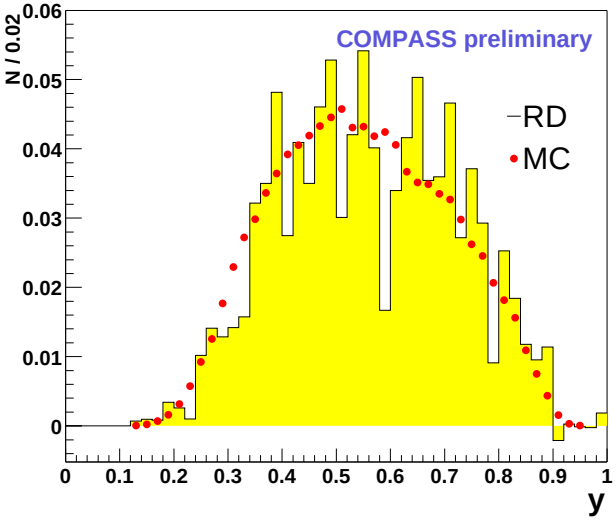


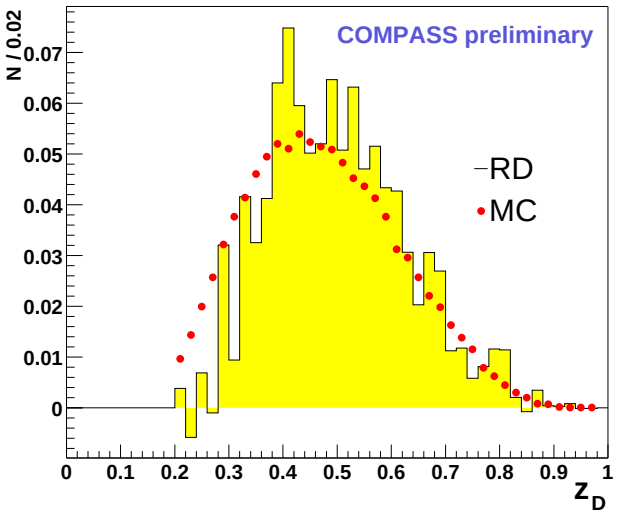
Open charm: Kinematic Distributions

Comparison data vs. MC

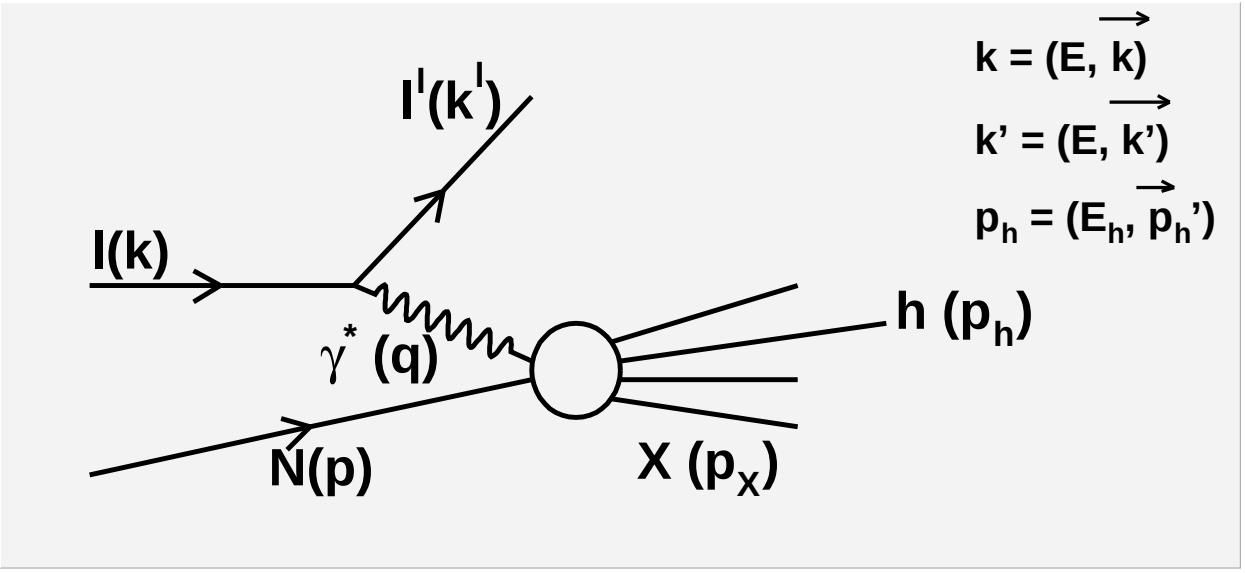








Deep Inelastic Scattering $l + N \rightarrow l' + X$



$l + N \rightarrow l' + X$:	inclusive process
$l + N \rightarrow l' + h + X$:	semi-inclusive process

Deep Inelastic Scattering $l + N \rightarrow l' + h + X$

For inclusive process:	
$Q^2 = -(k - k')^2 = -q^2$	4 momentum transfer
$\nu = \frac{p \cdot q}{M} = E - E'$	energy transfer in LAB (TRF)
$x = \frac{Q^2}{2p \cdot q} = \frac{Q^2}{2M\nu}$	Bjorken variable $(0 < x < 1)$
$y = \frac{p \cdot q}{p \cdot k} = \frac{\nu}{E}$	rel. energy transfer
$W^2 = (p + q)^2$	mass of hadronic final state W $\approx>$ 2 GeV $\Rightarrow$ DIS
For semi-inclusive process:	
$z = \frac{p \cdot p_h}{p \cdot q} = \frac{E_h}{\nu}$	energy fraction of virtual photon carried by hadron $(0 < z < 1)$
p_T	transverse momentum with respect to virtual photon