New COMPASS results on the gluon polarisation using D^0 production asymmetries

DIS 2010 - Firenze

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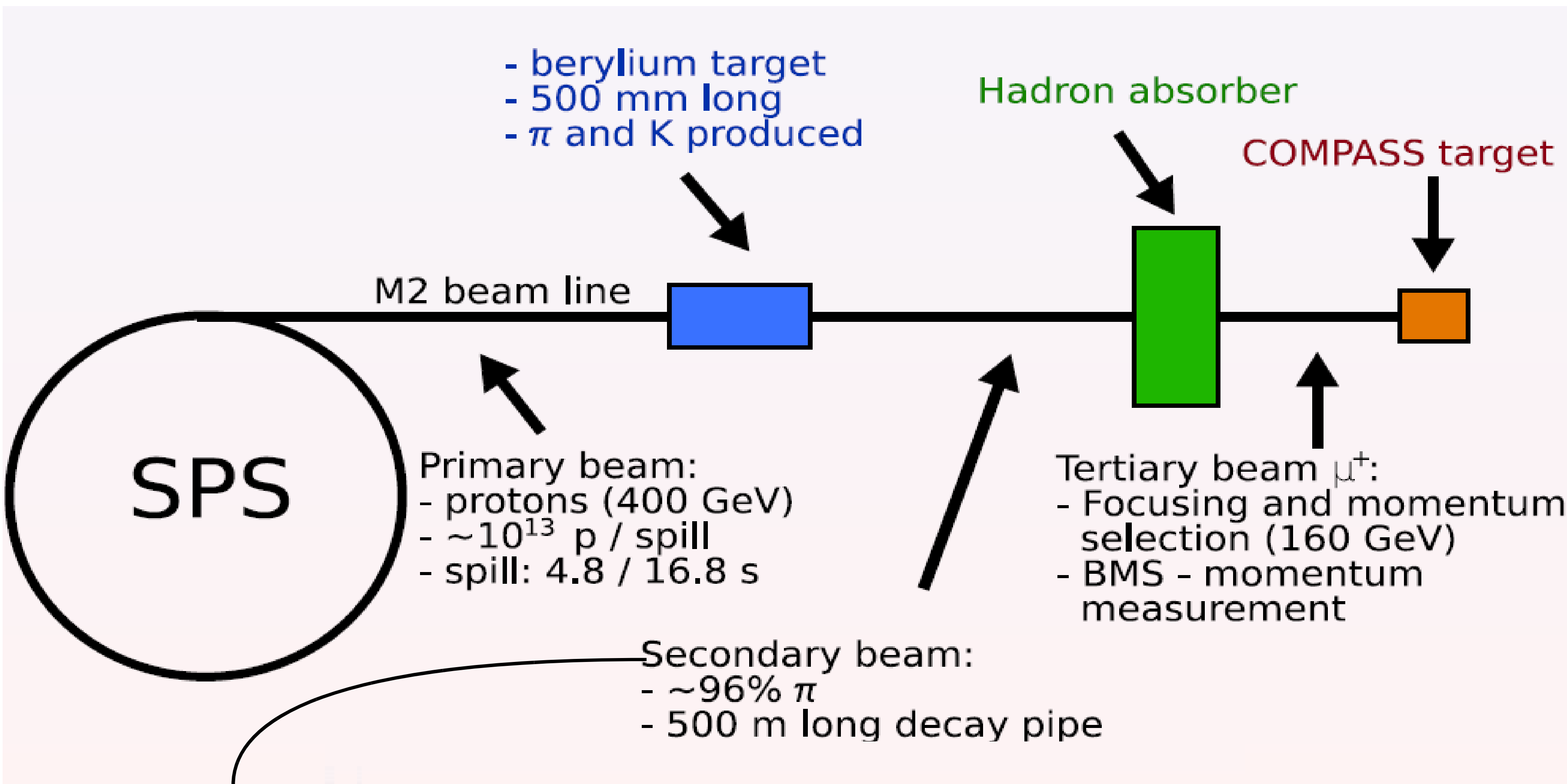
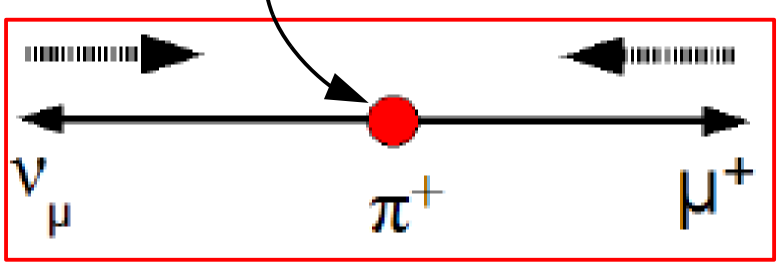
on behalf of the COMPASS collaboration

The COMPASS polarised beam

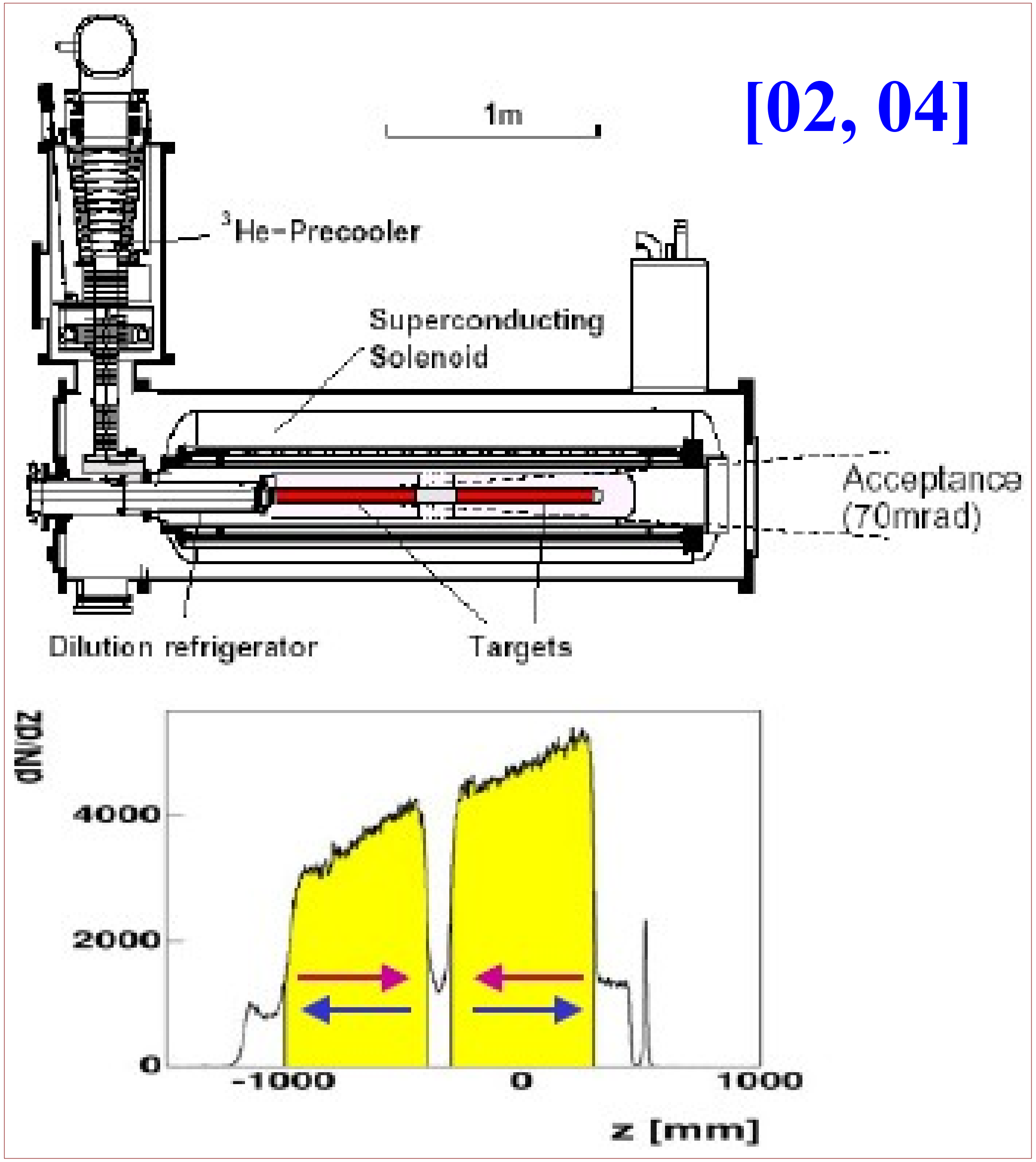




Naturally polarised muon beam: $P_{\mu} \sim 80\%$

The COMPASS polarised target: [02, 06] and 2007 data

- Target material: $^{6}LiD/NH_3$ - Solenoid field: 2.5 T - Dilution factor: f ~ 0.4/0.15
- Polarisation: $P_T > 50\%/90\%$ - $^{3}He/^{4}He$: $T_{min} \sim 50$ mK

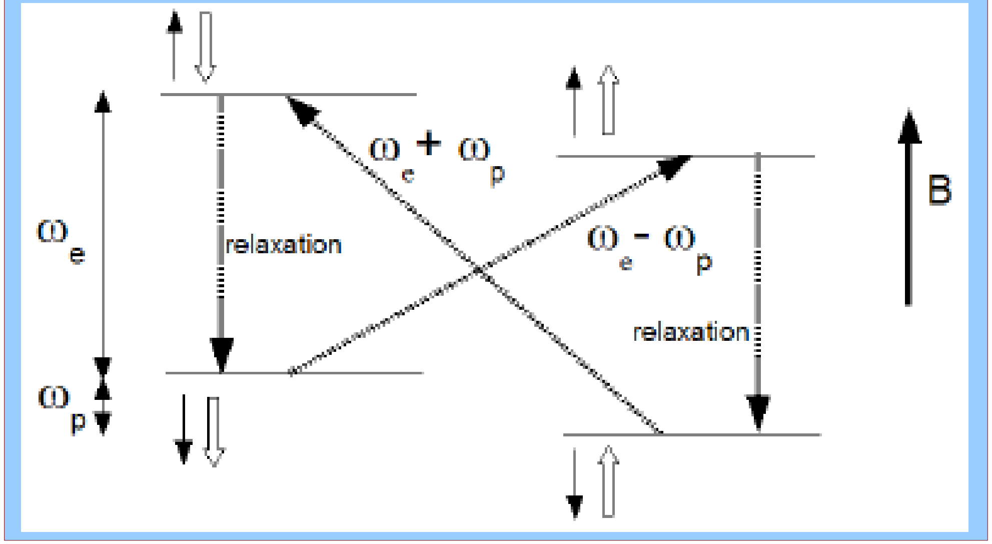


2006 and 2007 data

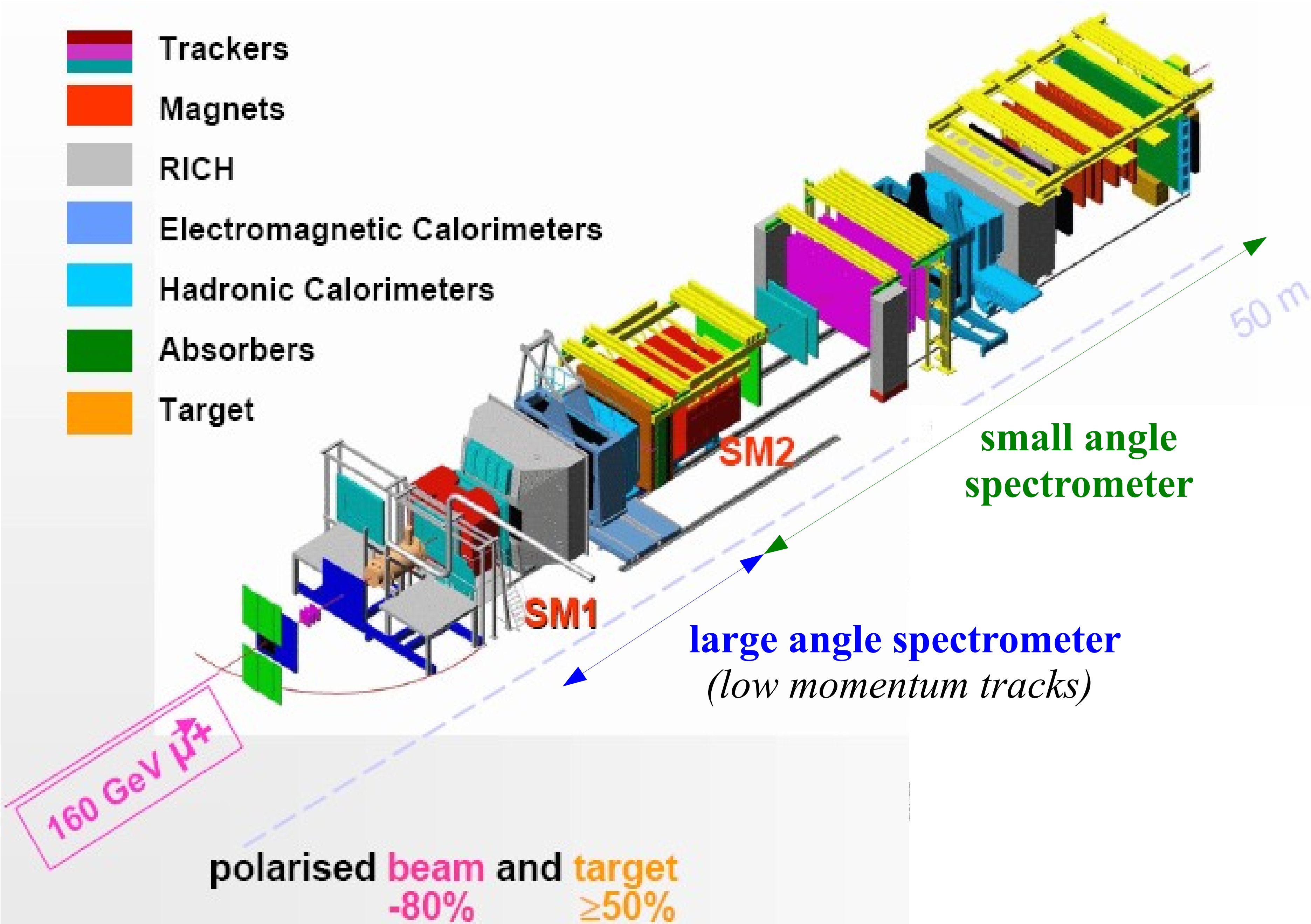
3 cells inside 180 mrad of acceptance

Dynamic nuclear polarisation:

- Microwave irradiation of material, for simultaneous flip of electron and nucleon spin
- Nucleons mantain their spin orientation due to a long relaxation time *(low μ_B)*



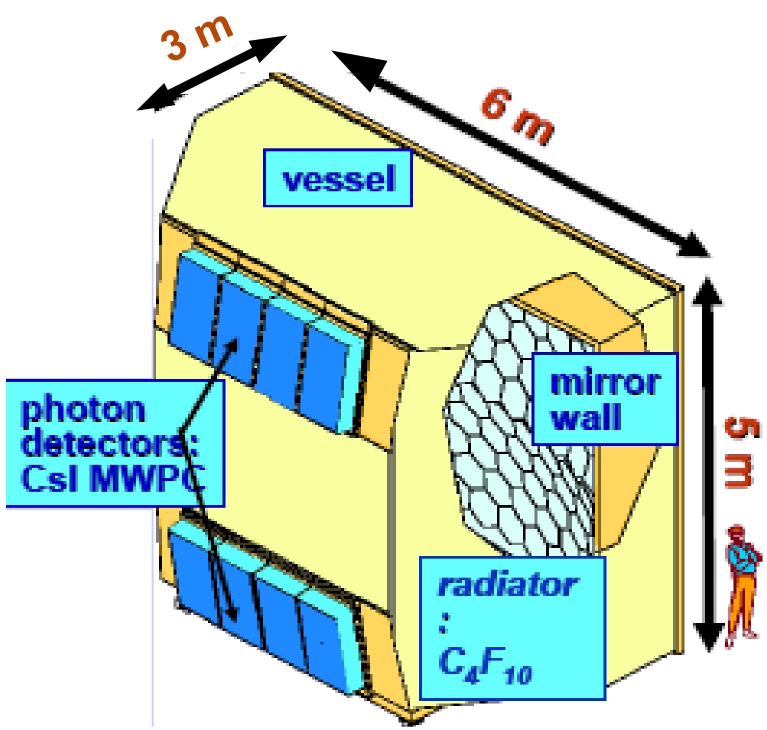
The COMPASS spectrometer



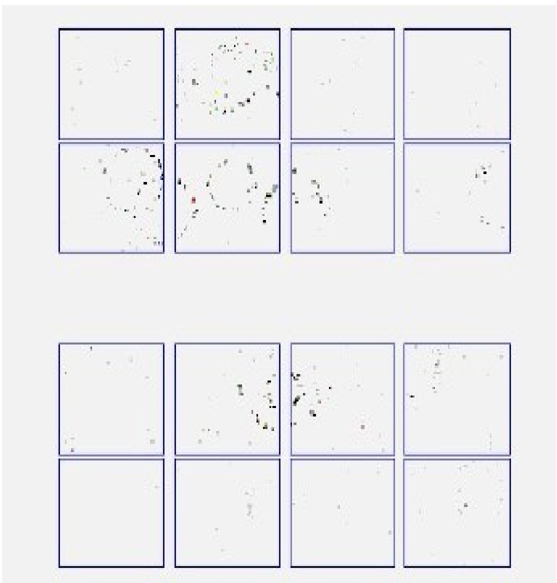
small angle spectrometer

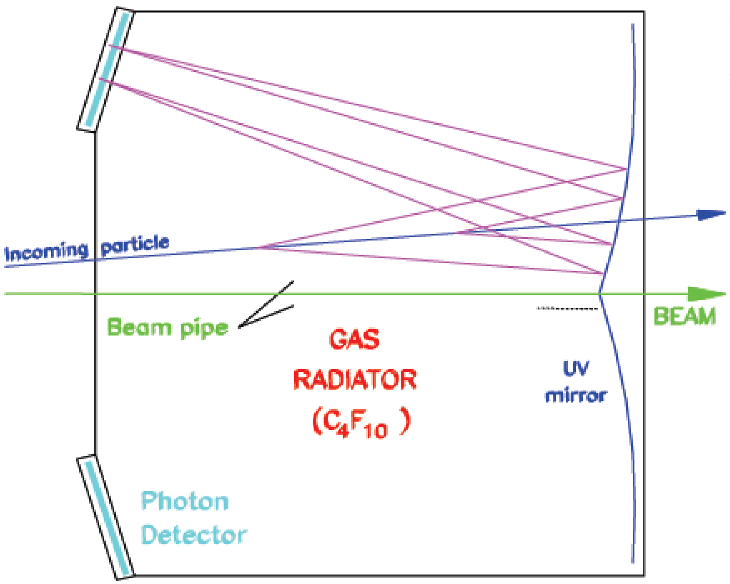
large angle spectrometer
(low momentum tracks)

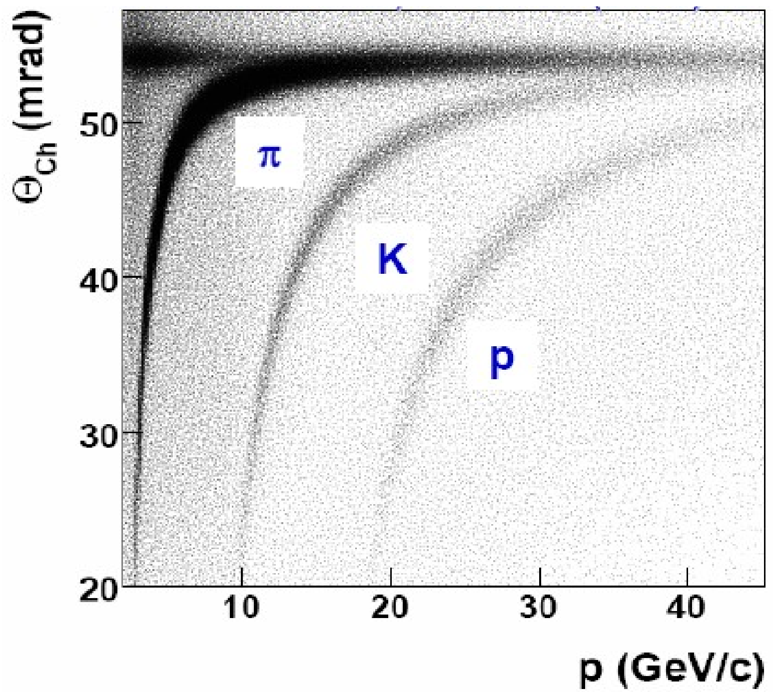
Particles identification: Ring Image Cherenkov *(RICH)*



- π, K separation: until P ~ 50 GeV/c
- 80 m^3 filled with C_4F_{10}: n = 1.00153
- 116 VUV spherical mirrors *(21 m^3)*
- 5.3 m^2 photodetectors: 82944 pixels







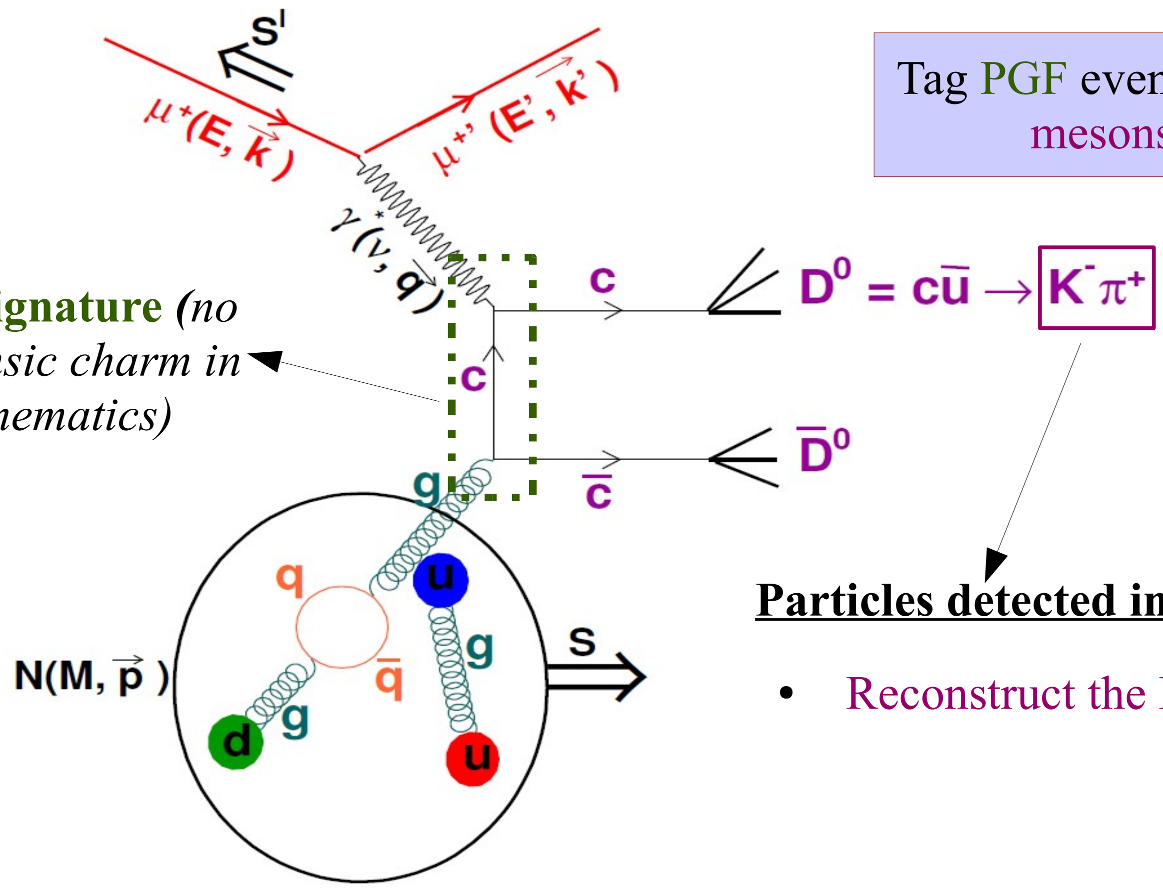
How to tag a polarised gluon?

- **In COMPASS, one can scan directly the gluons using the following interaction**:

The photon-gluon fusion process *(LO-PGF)*

Tag PGF events via Open-Charm mesons production

Clean PGF signature ***(****no nucleon intrinsic charm in COMPASS kinematics)*



__Particles detected in the spectrometer__:

- Reconstruct the D^0 invariant mass!

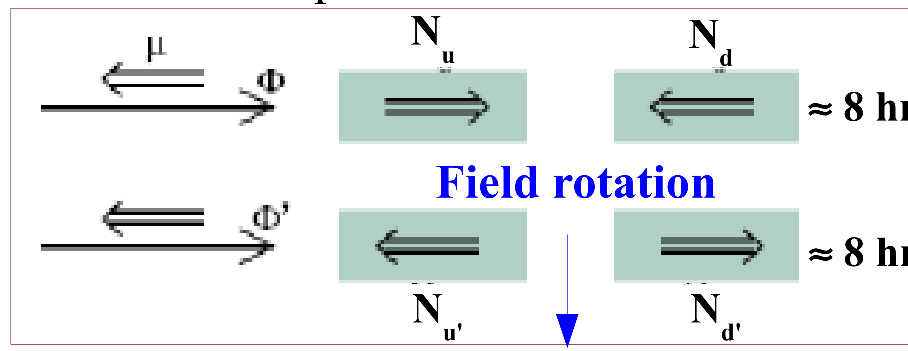
Measuring D^0 asymmetries to extract ΔG

- **The number of reconstructed D^0** *($N^{u/d}$)* **can be used to** **measure an Open-Charm asymmetry for the PGF interaction** *(considering $A^B = 0$)*:

$$A^{exp} = \frac{1}{2}\left(\frac{N^u - N^d}{N^u + N^d} + \frac{N^{d'} - N^{u'}}{N^{u'} + N^{d'}}\right) = f \cdot P_\mu \cdot P_T \cdot \frac{s}{s+b} \cdot A^{\mu,T}$$

Open-Charm event probability

upstream cell downstream cell



equal acceptance for both cells

- **In LO QCD, the physical asymmetry can be interpreted in the following way:**

$$A^{\mu,T} = \langle a_{LL} \rangle \frac{\Delta G}{G} \quad \text{with} \quad a_{LL} = \frac{\Delta \sigma^{PGF}}{\sigma^{PGF}}$$

asymmetries are less sensitive to experimental changes

- **Weighting each event with $\omega = (f \cdot P_\mu \cdot S/(S+B) \cdot a_{LL})$:** → **needed for every event**

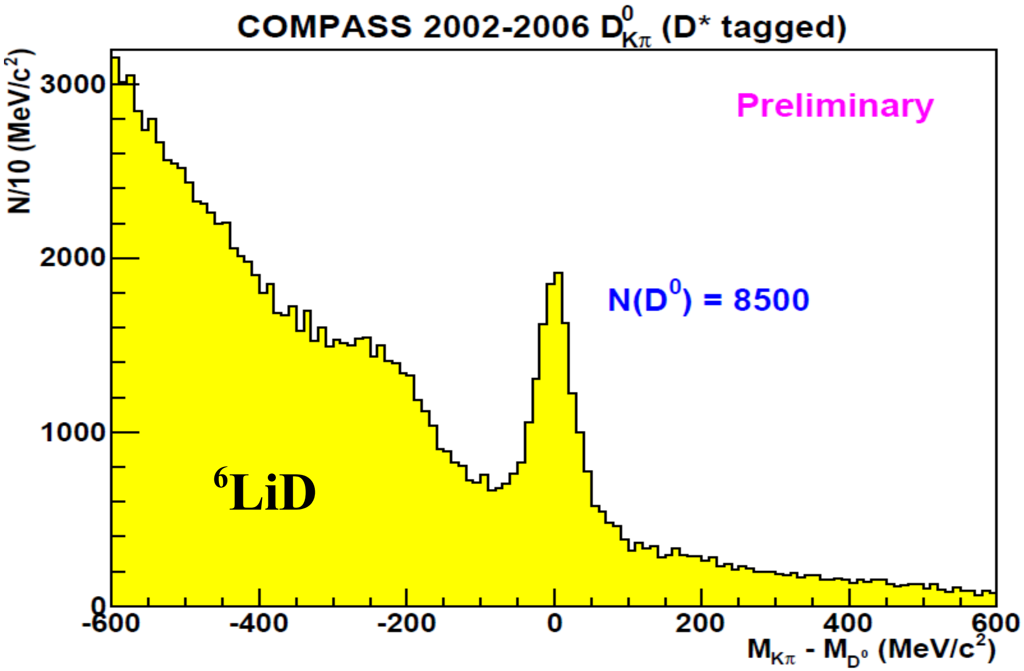
$$\frac{\Delta G}{G} = \frac{1}{2P_T} \times \left(\frac{\omega_u - \omega_d}{\omega_u^2 + \omega_d^2} + \frac{\omega_{u'} - \omega_{d'}}{\omega_{u'}^2 + \omega_{d'}^2}\right) \quad \text{with a statistical gain} : \frac{\langle \omega^2 \rangle}{\langle \omega \rangle^2}$$

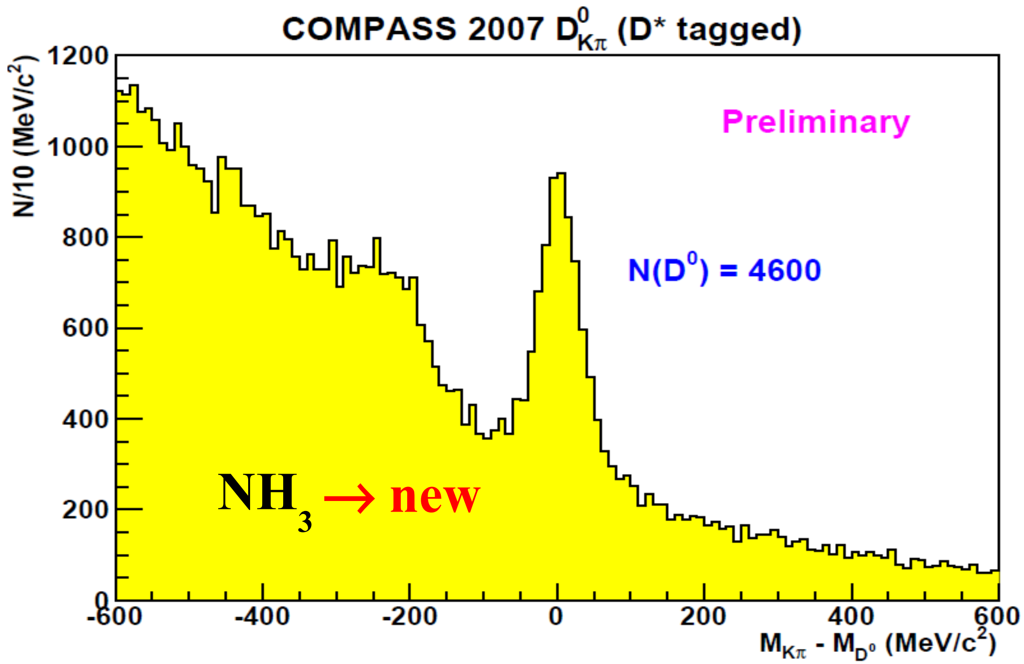
Open-Charm mesons reconstruction

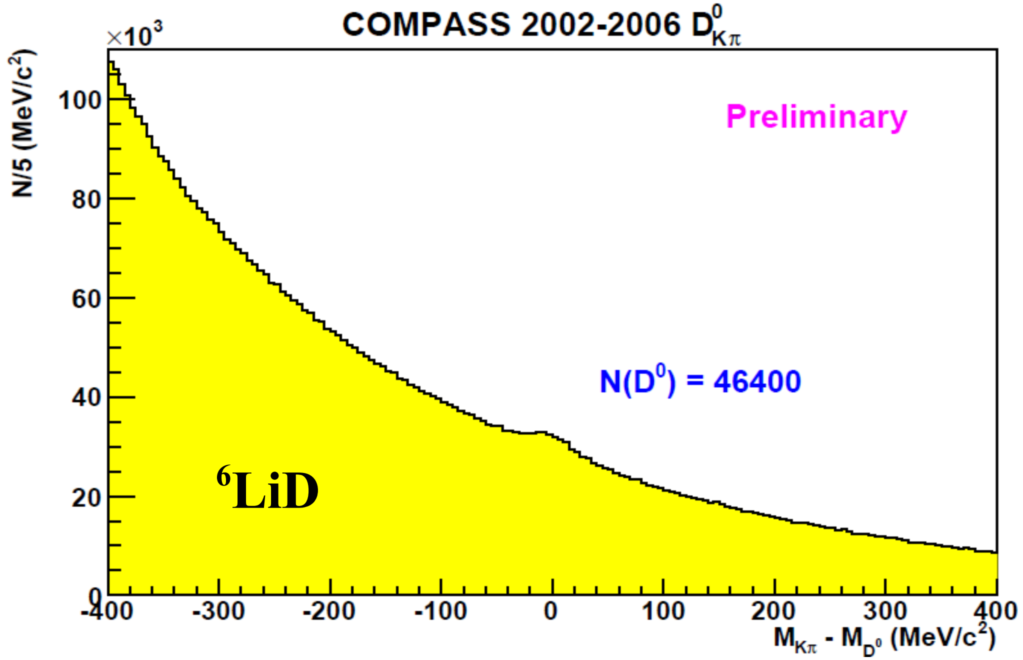
- **Events considered** *(resulting from the c quarks fragmentation)***:**
  - $D^0 \rightarrow K\pi$ *(BR: 4%)*
  - $D^* \rightarrow D^0\pi_S$ *(30% D^0 tagged with a D^*)*
    - $D^0 \rightarrow K\pi$
    - $D^0 \rightarrow K\pi\pi^0$ *(BR: 13%)* ► **not directly reconstructed**
    - $D^0 \rightarrow K\pi\pi\pi$ *(BR: 7.5%)*
    - $D^0 \rightarrow sub(K)\pi$ ► **no RICH ID for Kaons** *($p < 9$ GeV/c)*

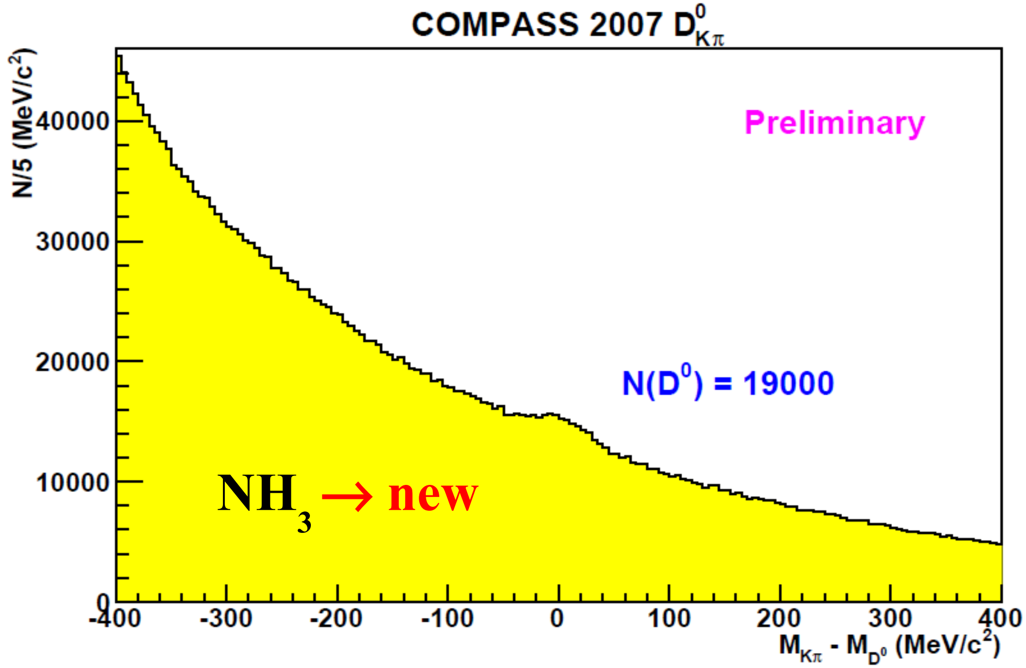
- **Selection to reduce the combinatorial background:**
  - **Kinematical cuts:** Z_D and D^0 decay angle *(to reject colinear events with γ^* coming from the nucleon fragmentation)*, K and π momentum
  - **RICH identification:** K and π ID + electrons rejected from the π_s sample
  - Mass cut for the D^* tagged channels *($M[K\pi\pi_S] - M[K\pi] - M[\pi]$)*
  - Neural Network qualification of events

Invariant Mass Spectrum: $D^0_{K\pi}$ *(D* tagged and untagged channels)*

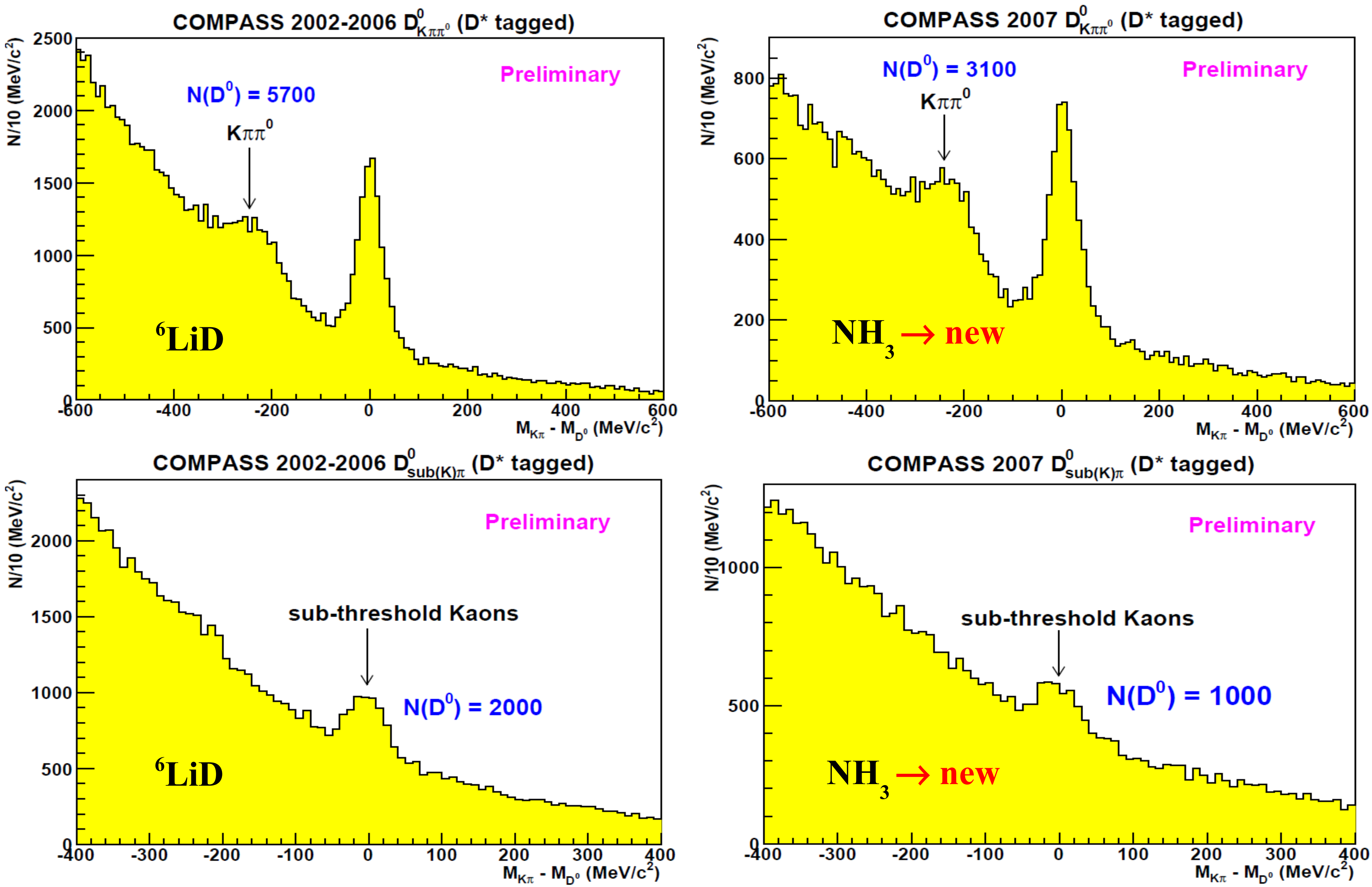




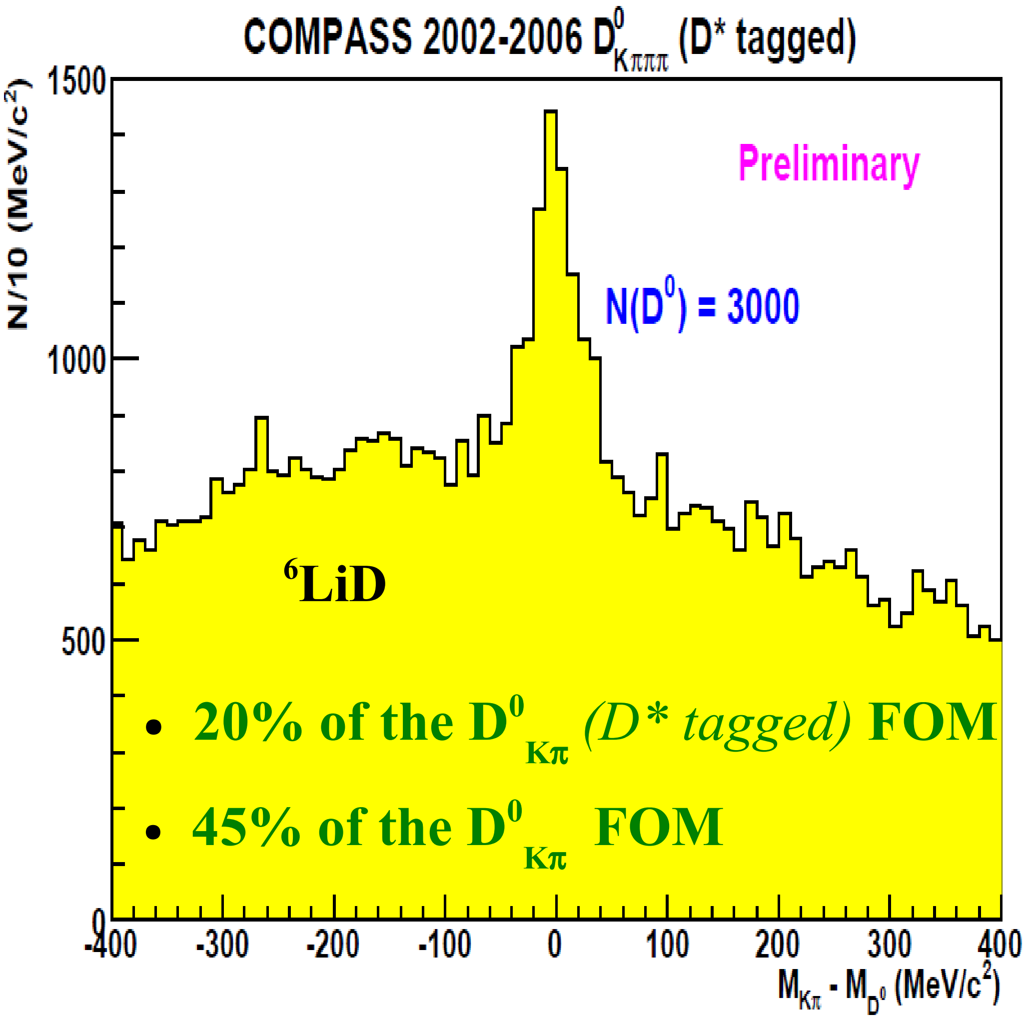




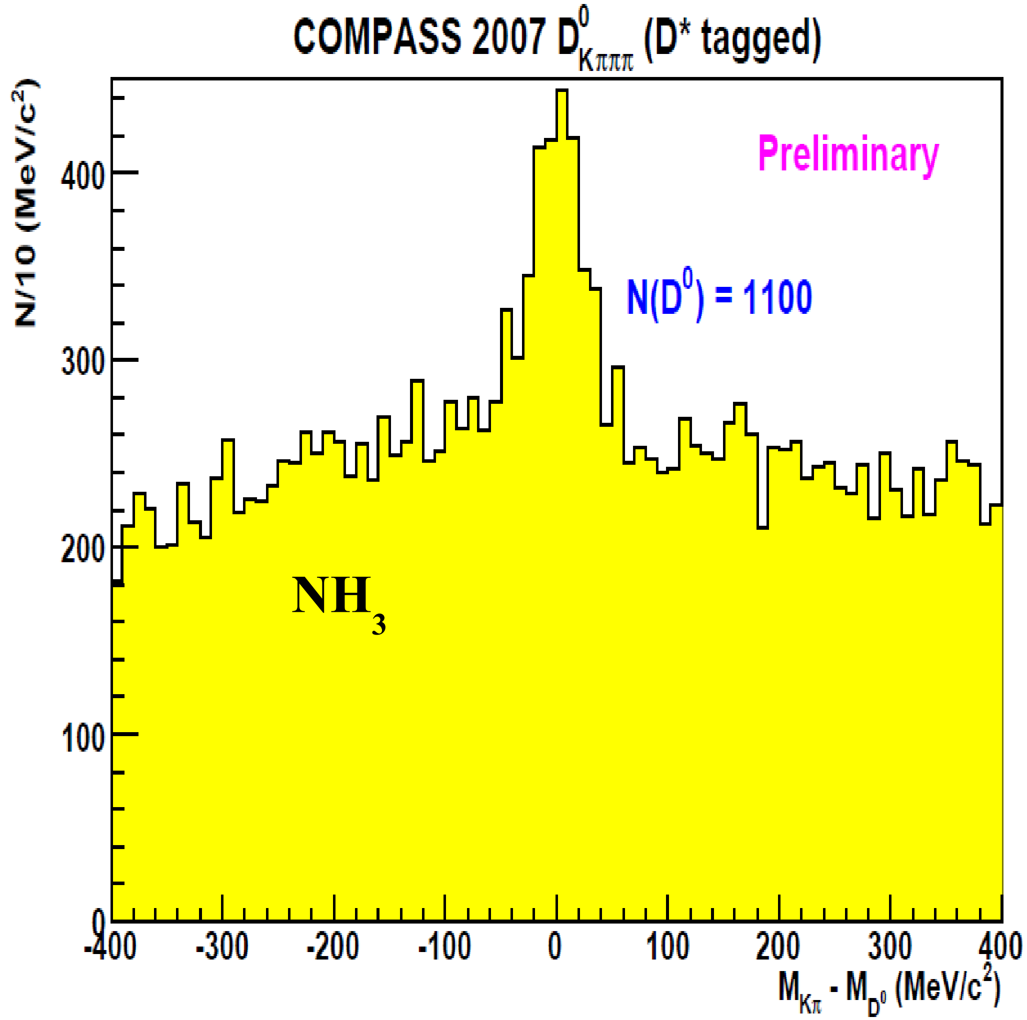
Invariant Mass Spectrum: $D^0_{K\pi\pi^0}$ and $D^0_{sub(K)\pi}$ *(D* tagged channels)*



Invariant Mass Spectrum: $D^0_{K\pi\pi\pi} \rightarrow$ New D* tagged channel



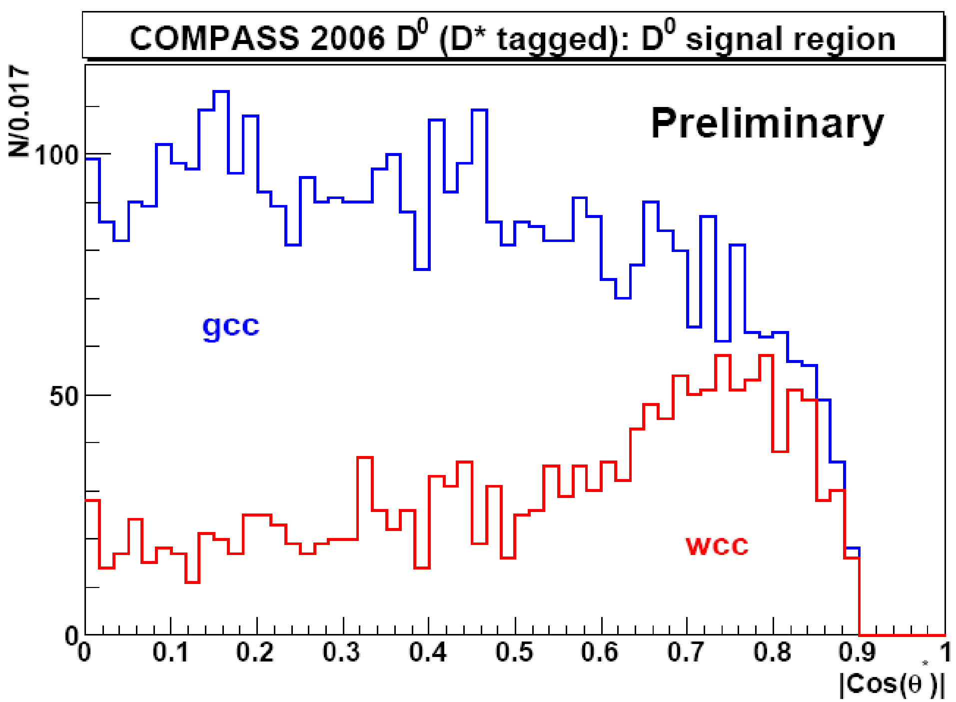
- 20% of the $D^0_{K\pi}$ *(D* tagged)* FOM
- 45% of the $D^0_{K\pi}$ FOM

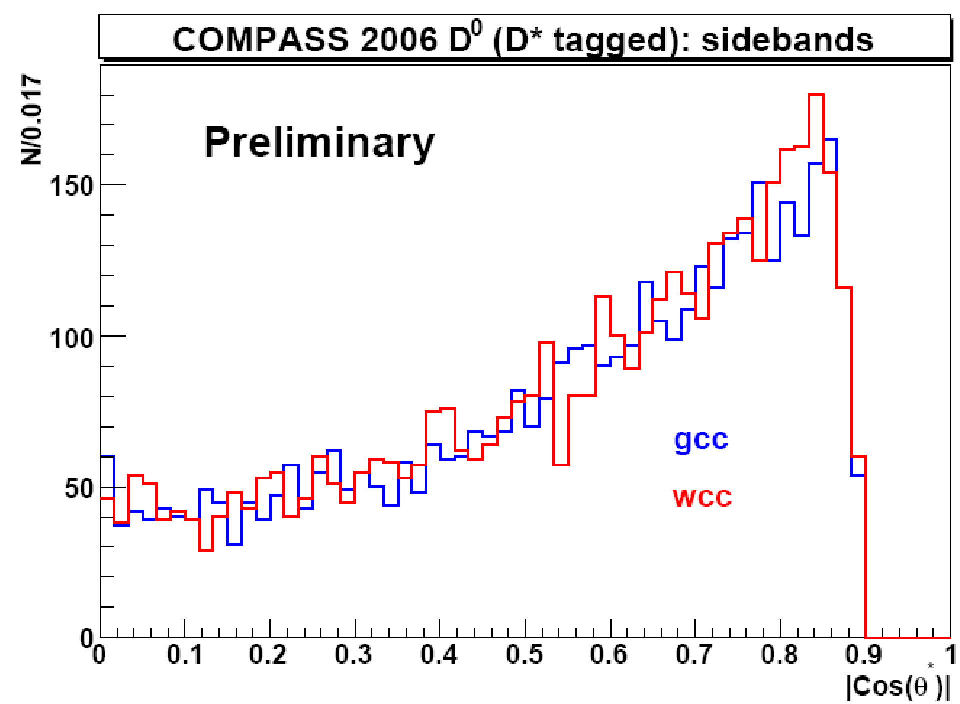


Neural Network qualification of events

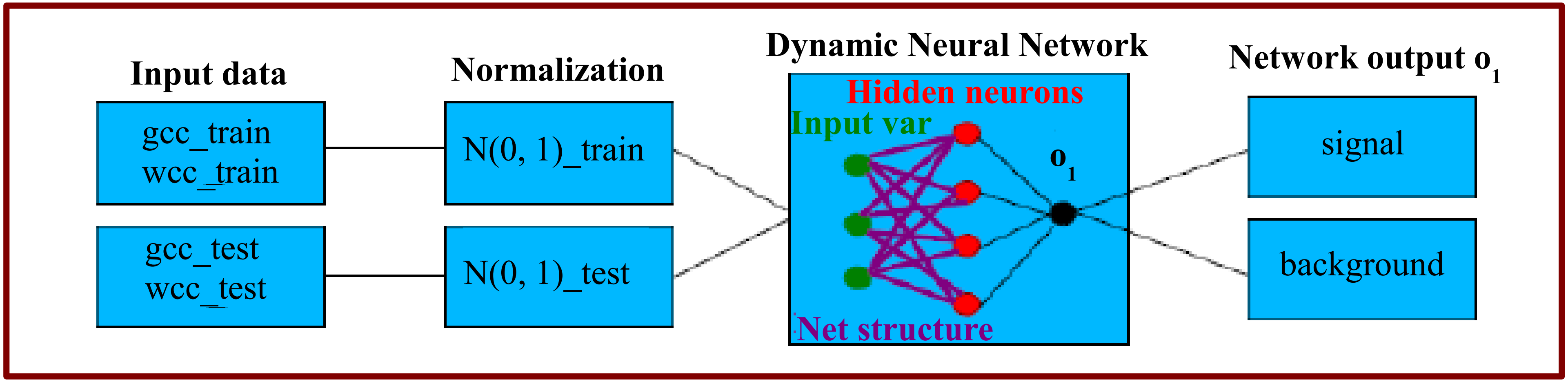
- **Two real data samples** *(with the same cuts applied)* **are compared by the Neural Network** *(<u>using some kinematic variables as a learning vector</u>)*:
  - **Signal model** → **gcc** = $\mathbf{K}^{+}\pi^{-}\pi_{\mathbf{s}}^{-}$ + $\mathbf{K}^{-}\pi^{+}\pi_{\mathbf{s}}^{+}$ *(D^{0} spectrum: signal + background)*
  - **Background model** → **wcc** = $\mathbf{K}^{+}\pi^{+}\pi_{\mathbf{s}}^{-}$ + $\mathbf{K}^{-}\pi^{-}\pi_{\mathbf{s}}^{+}$ *(no D^{0} is allowed)*
- **If the background model is good enough:** <u>The Neural Network is able to distinguish the signal from the combinatorial background on a event by event basis</u> *(inside gcc)*

Example of a good learning variable





$s/(s+b)_{NN}$: Neural Network *(NN)* parameterisation



- **Neural Network initialization:** number of neurons + random structure weights
- **<u>The goal is to tune the weights of each variable-neuron connection</u>:** They are iteratively adjusted to minimize the error between the expected answer *(0.95/0.05 for gcc/wcc)* and the neuron response *(modulated by a sigmoid activation function)*
- **To ensure universality 2 data sets** *(train and test)* **are used:**
  - If their errors start to diverge the learning strategy is changed: Redundant neurons are killed *(new ones can born)* ⇒ <u>Independence of precise initial conditions</u>!
- **D^0 probabilities are computed, <u>for every gcc event</u>, using the resulting multidimensional parameterisation** *(NN structure)*: $f(o_1) = s/(s+b)_{NN}$

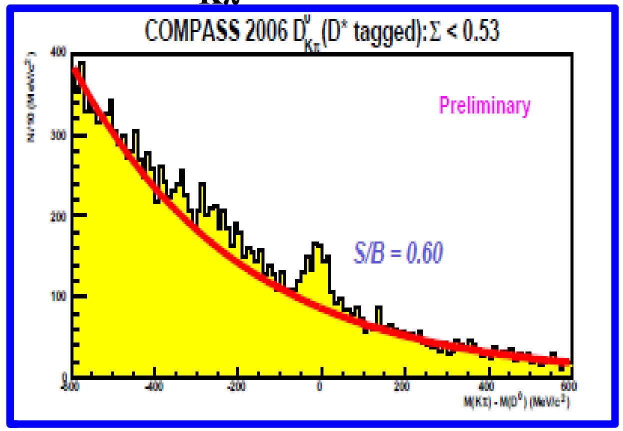
s/(s+b): Obtaining final probabilities for a D^0 candidate

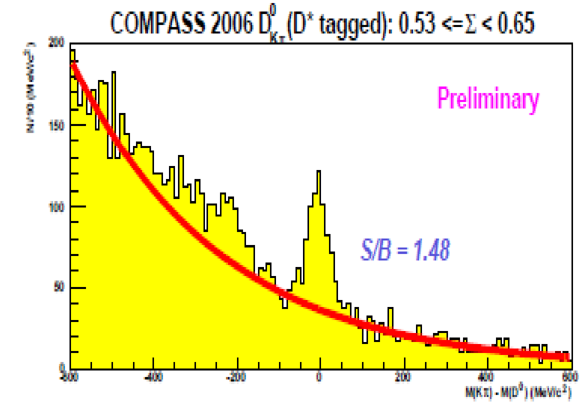
- **Events with small s/(s+b)$_{NN}$**
  - Mostly combinatorial background is selected

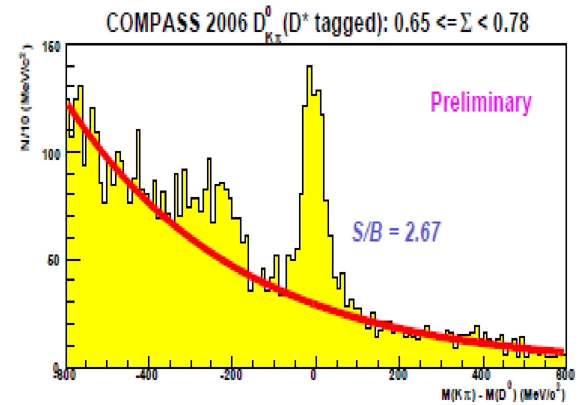
<u>s/(s+b) is obtained from a fit inside this bins</u> *(correcting with the NN parameterisation)*

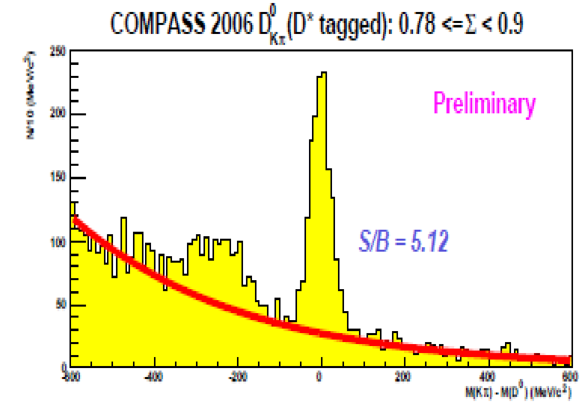
- **Events with large s/(s+b)$_{NN}$**
  - Mostly Open-Charm events are selected

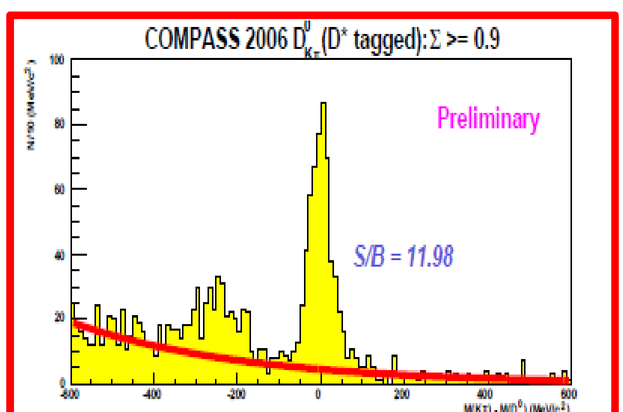
$D^0_{K\pi}$ tagged spectrum in bins of Σ = s/(s+b)$_{NN}$





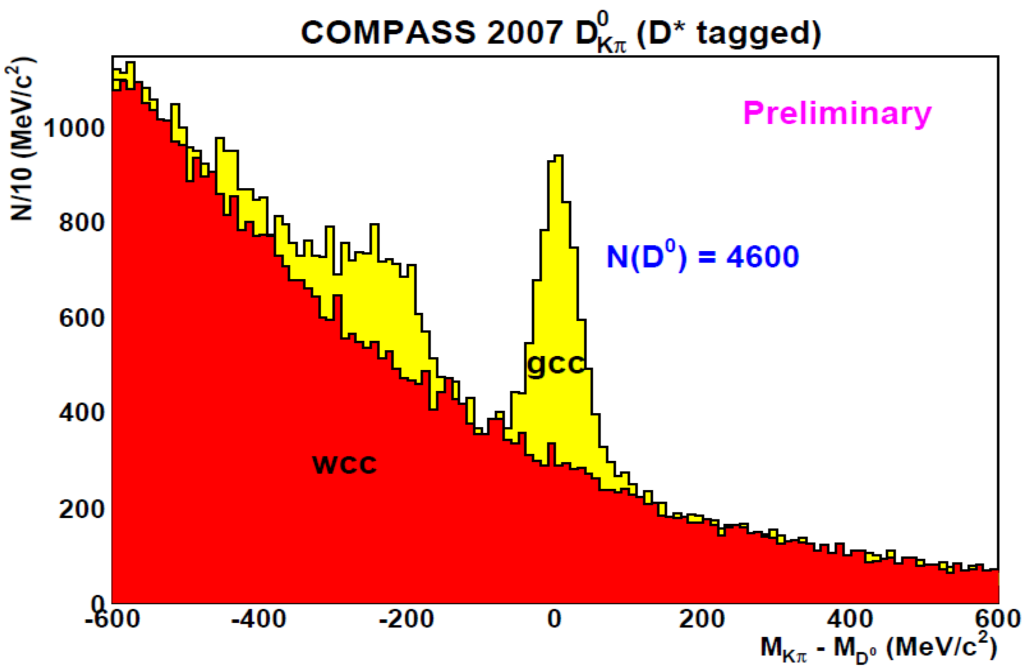


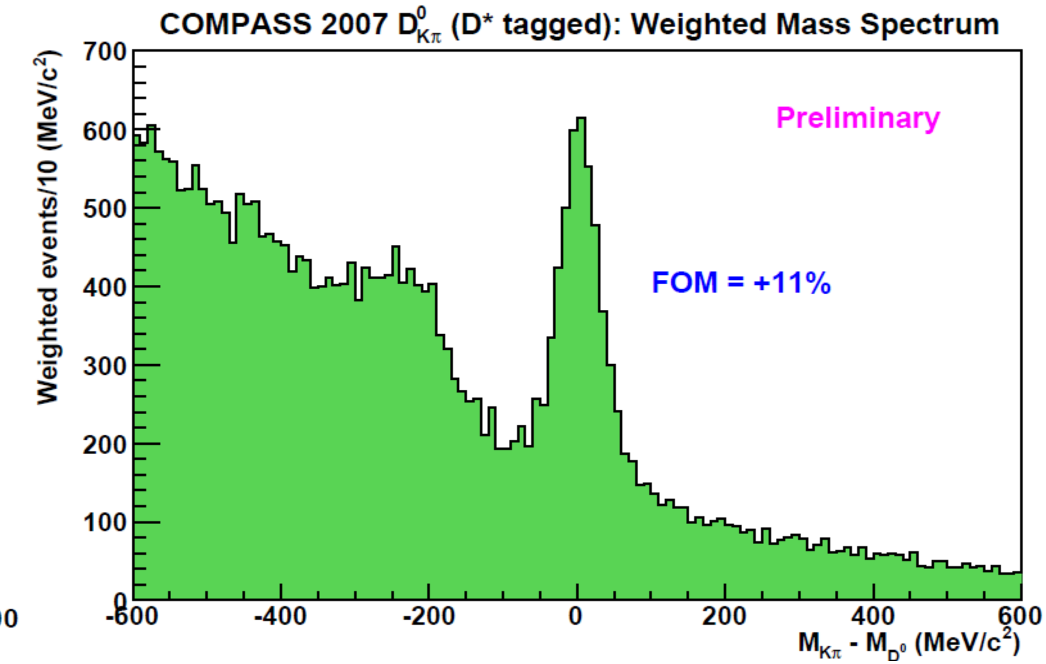


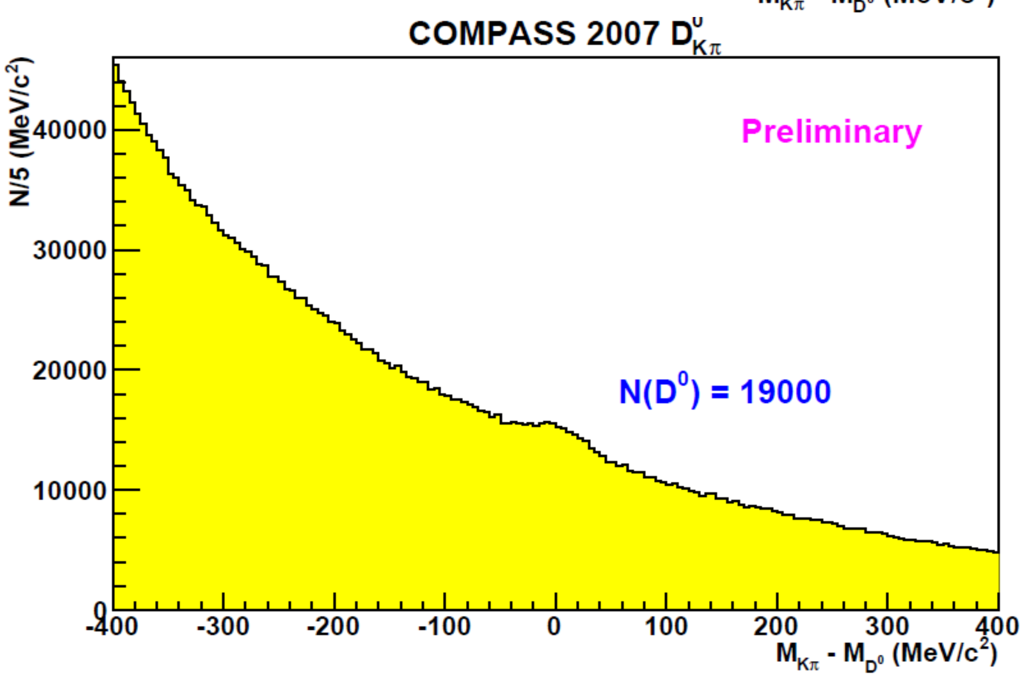


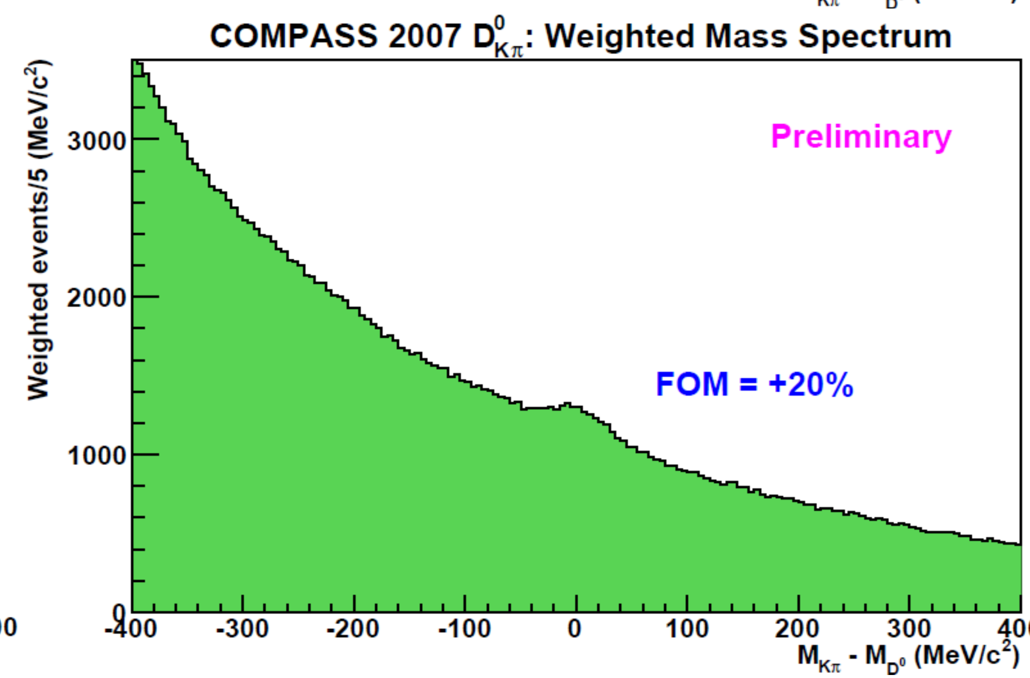
$$\delta\left(\frac{\Delta G}{G}\right) \propto \frac{1}{FOM}$$

S/(S+B) parameterisation: **FOM improvement** *(main channels)*

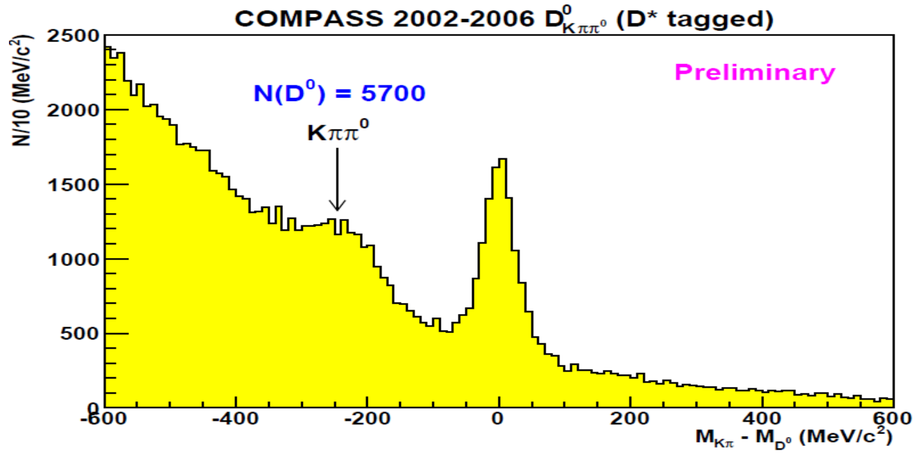


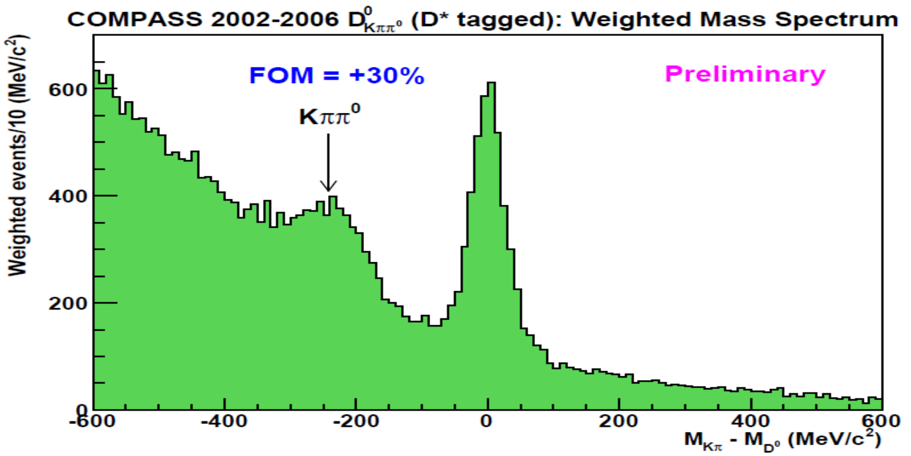


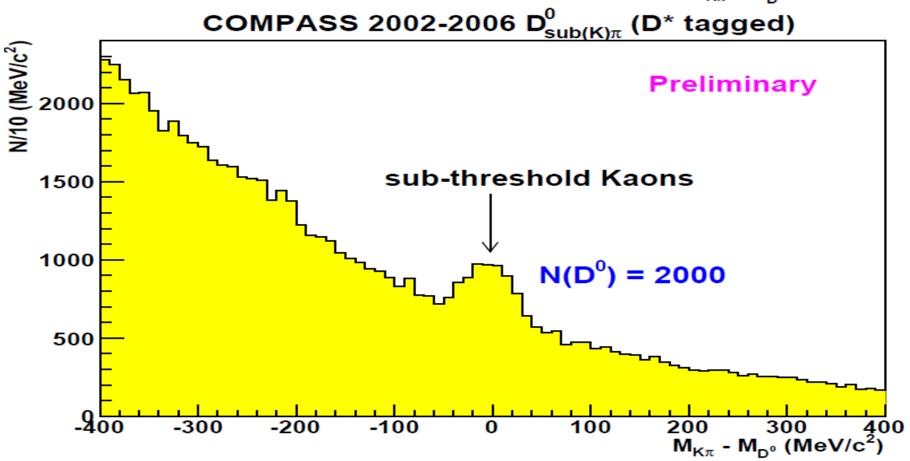


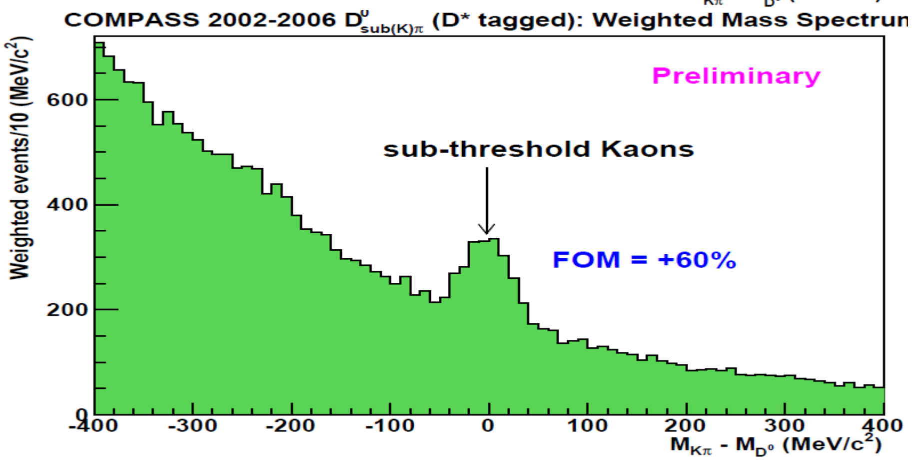


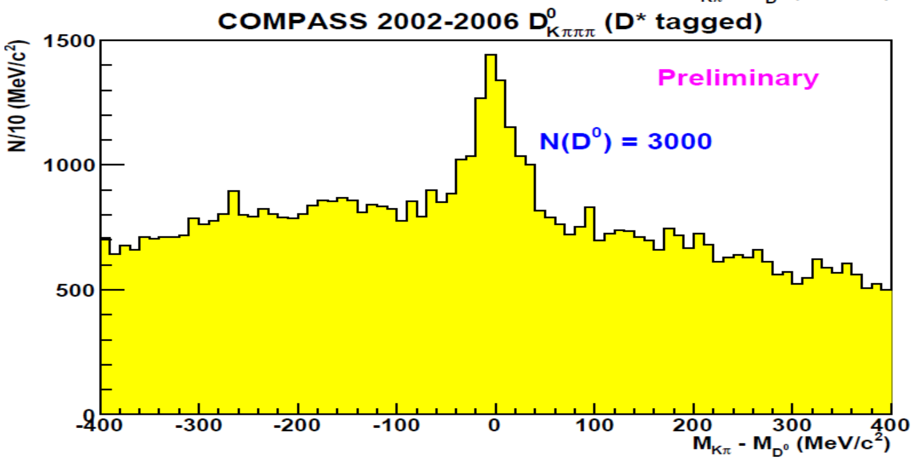
S/(S+B) parameterisation: FOM improvement *(low purity channels)*

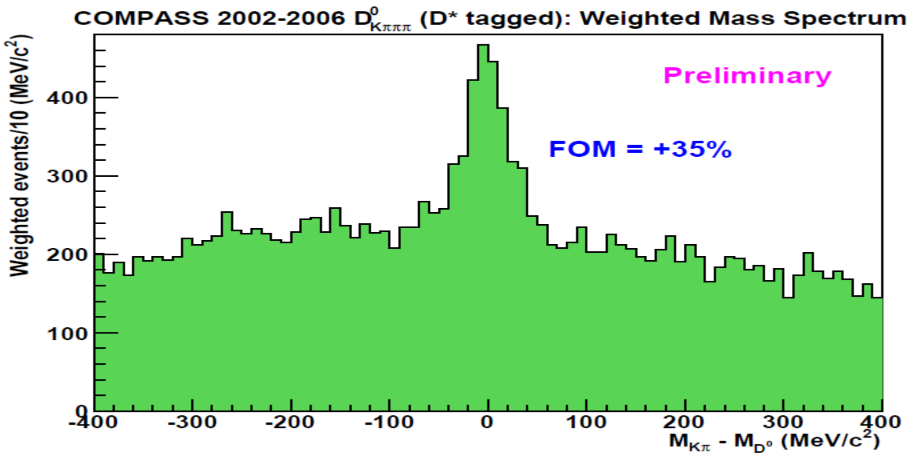








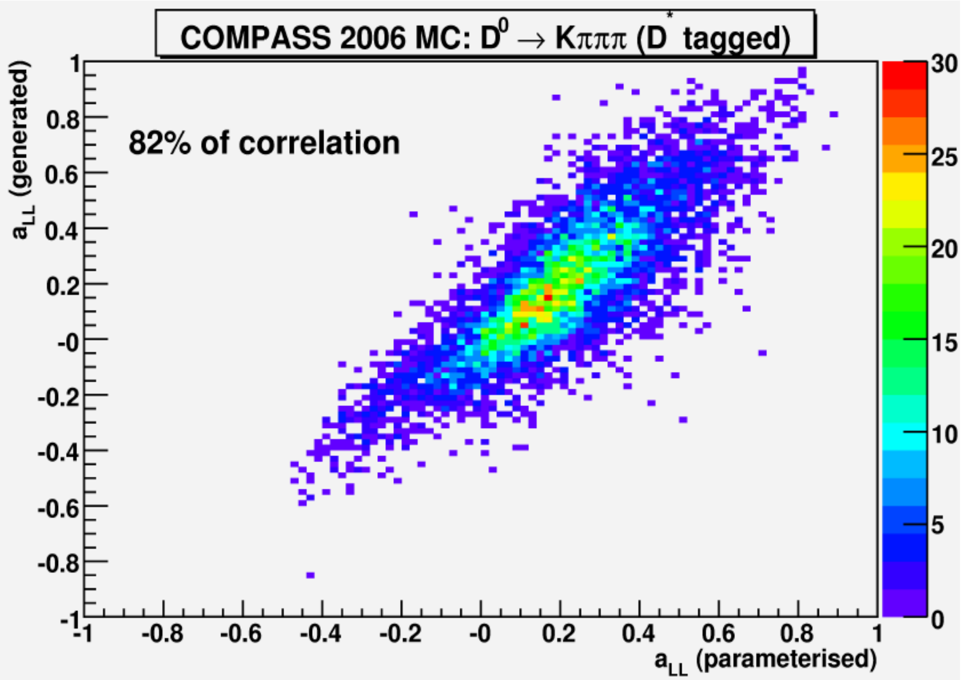




Partonic *(muon-gluon)* asymmetry a_{LL}

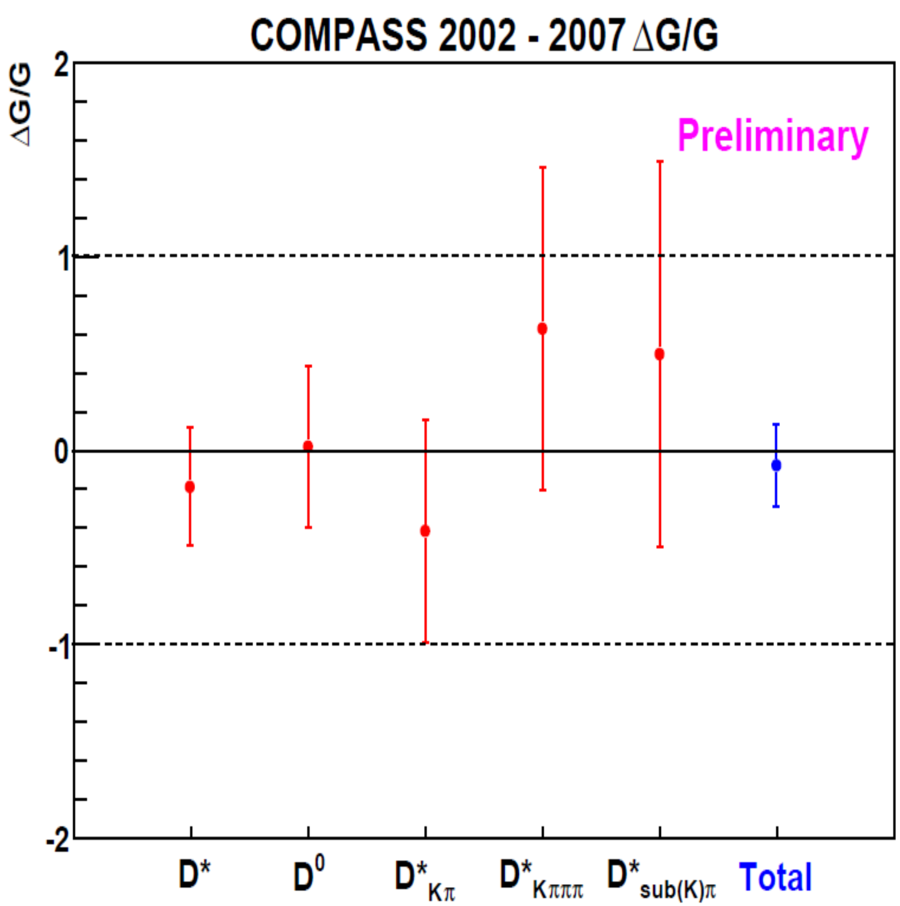
- a_{LL} **is dependent on the full knowledge of the partonic kinematics:**
  - $$a_{LL} = \frac{\Delta\sigma^{PGF}}{\sigma_{PGF}}(y, Q^2, x_g, z_C, \phi)$$
  - Can't be experimentally obtained: Only one charmed meson is reconstructed

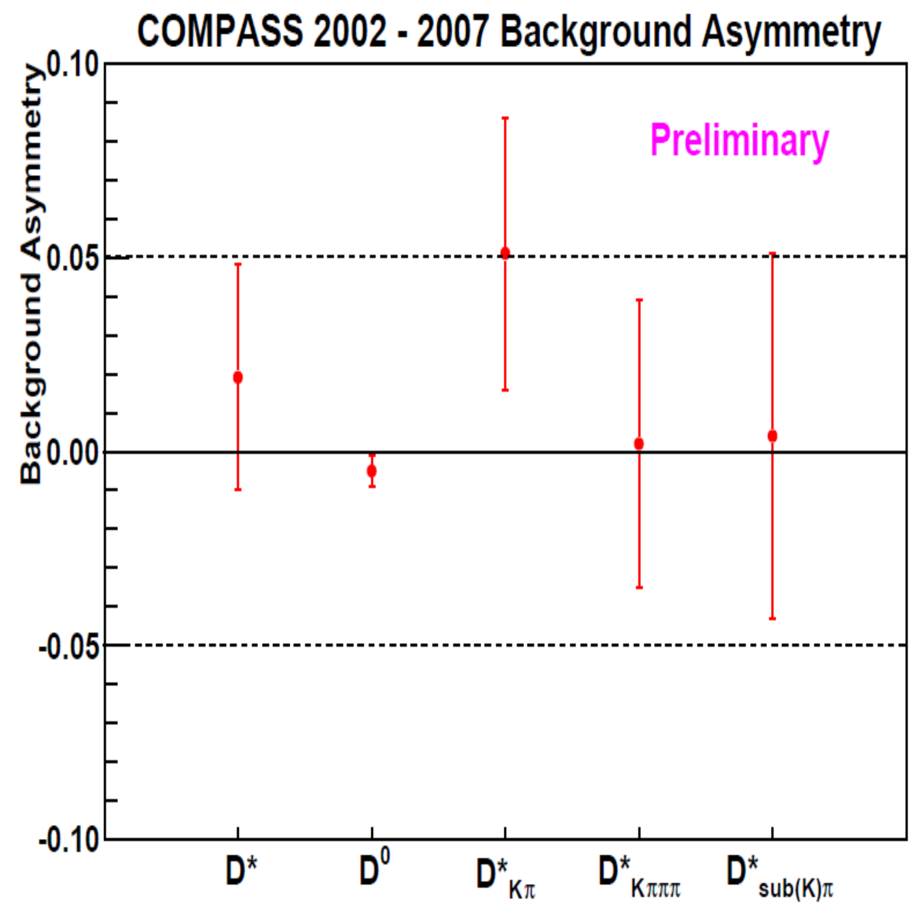
- a_{LL} **is obtained from Monte-Carlo** ***(in LO)*****, to serve as input for a Neural Network parameterisation on some reconstructed kinematical variables:** y, x_{Bj}, Q^2, z_D and p_T



Parameterised a_{LL}, shows a strong correlation with the generated one *(using AROMA)*

$\Delta G/G$: Final LO result

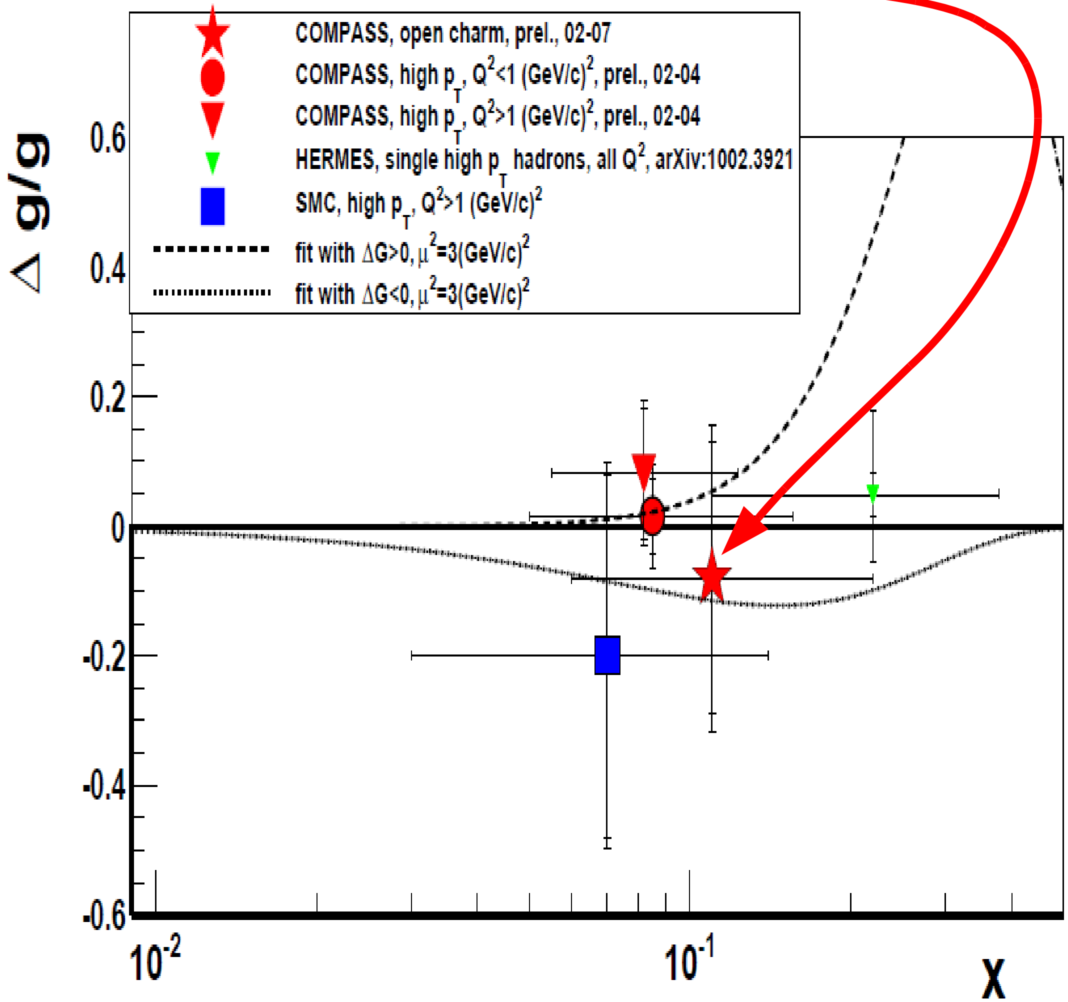




$$\frac{\Delta G}{G} = -0.08 \pm 0.21\ (\pm 0.11) \rightarrow @ <x_g> = 0.11,\ <\mu^2> = 13\ (\mathrm{GeV}/c)^2$$

Conclusions and prospects

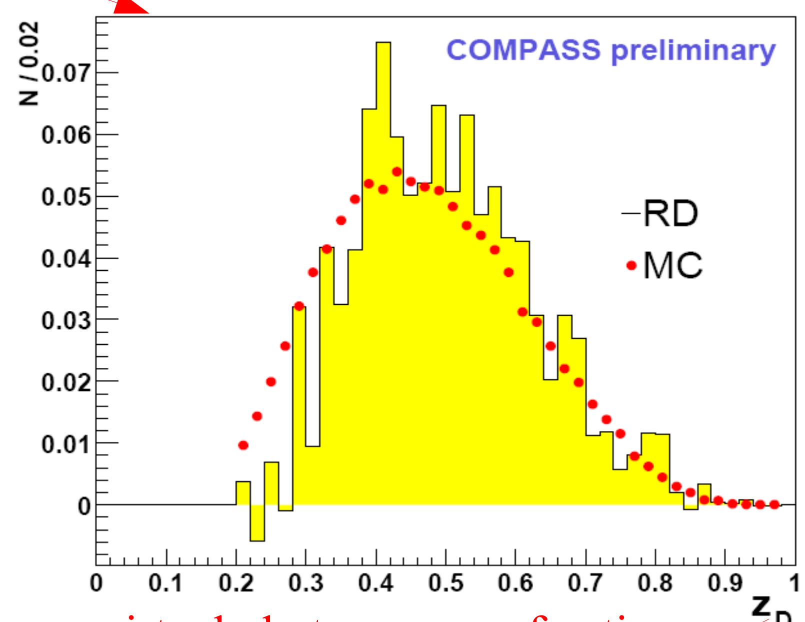
- **The gluon polarisation was obtained directly from the data, in LO, and was found to be <u>compatible with zero</u>**
- **All experimental measurements are in agreement:**
  - Small values of ΔG are preferred!
- **<u>Under study</u>:**
  - NLO analysis



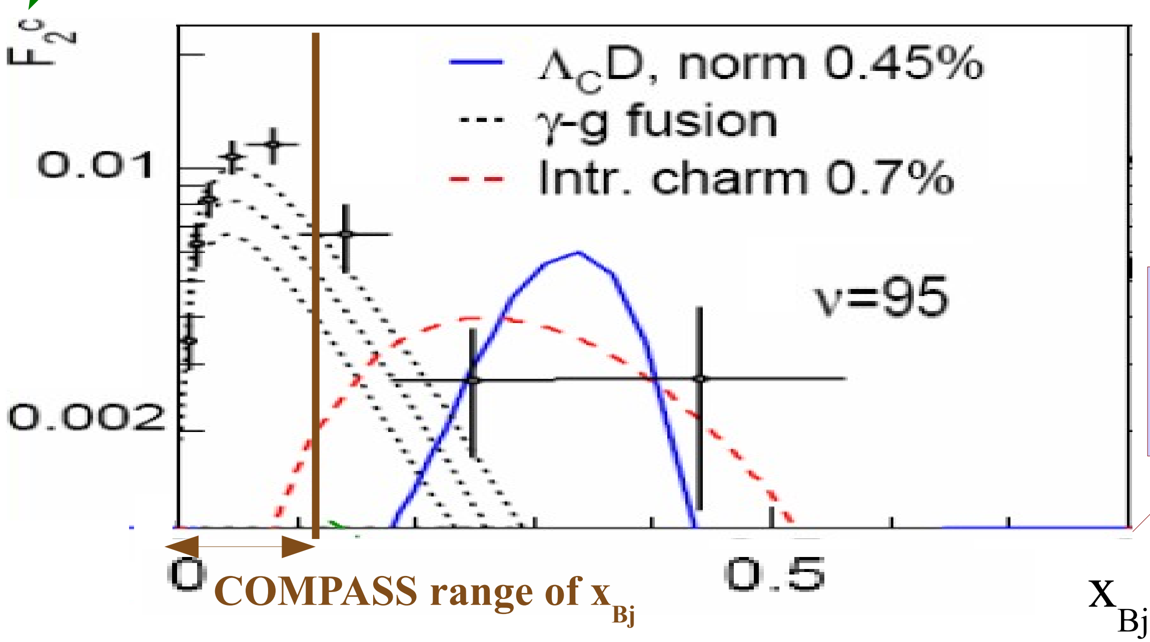
SPARES

Why measure the gluon polarisation from Open-Charm?

- **$c\bar{c}$ production is dominated by the PGF process** *(in LO)*, **and is <u>free from physical background</u>** *(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 the D^0 meson



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

Method to extract $\Delta G/G$ and the polarised A_B

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

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

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 $\omega_B = P_\mu \cdot f \cdot D(y) \cdot B/(S+B)$:

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

(cell = u , d , u' , d') **($\Delta G/G$)** **(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 the equations for the 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 â , 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 the same way before and after a field reversal:**

  8 $\Rightarrow$ <u>7 unknowns</u>: 5 â , 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:**

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