Λ polarization in electroproduction at CLAS

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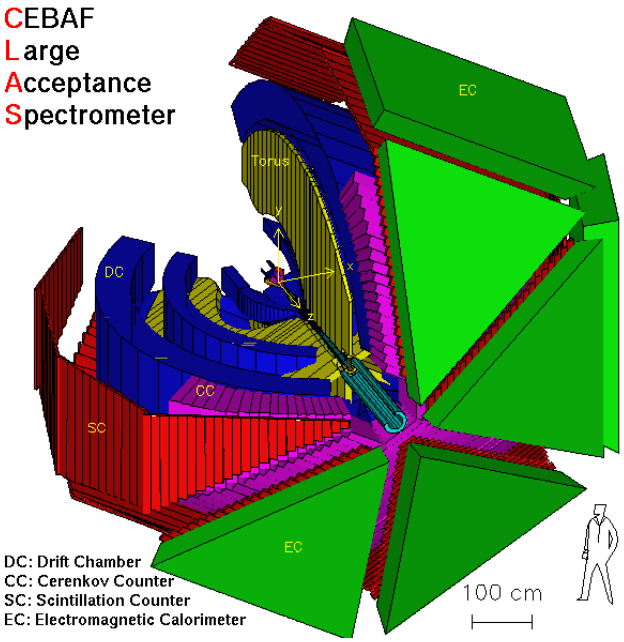
SIDIS Λ measurement

Data taken with CLAS detector in Hall-B at JLab (e1f run)

- **beam energy** — **5.5 GeV**
- **beam current** — **7 nA**
- **target** — **liquid H_2 L= 5cm**
- **average beam polarization** — **$P_B = 0.74 \pm 0.03$**



Channel selection

$$\vec{e}p \rightarrow e'\Lambda X$$
$$\hookrightarrow p\pi^-$$

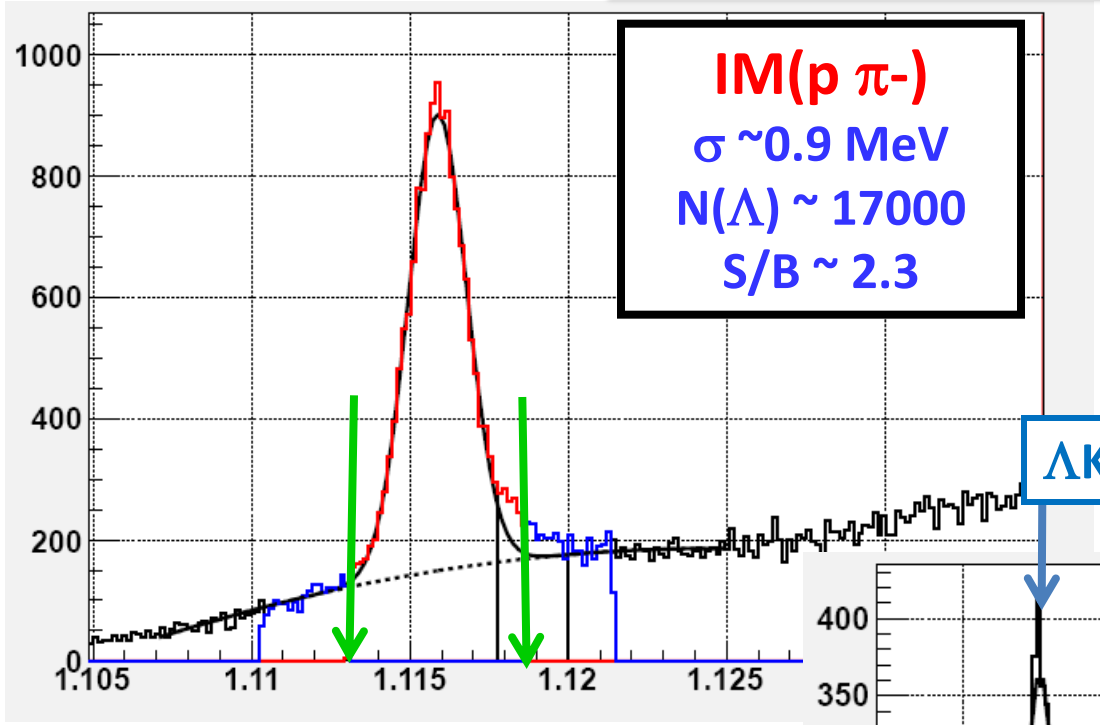
- **tight electron ID cuts (EC+CC)**
- **loose hadron ID cuts**

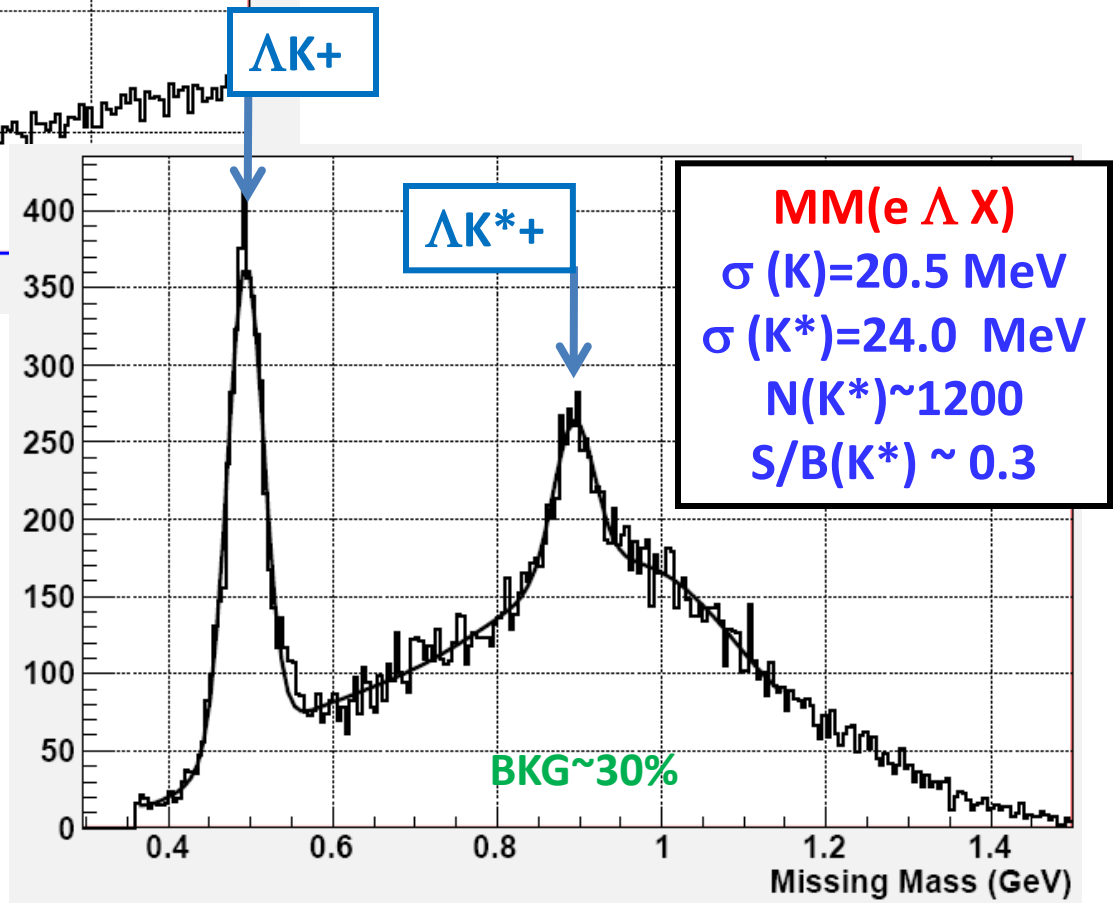
DIS cuts:

Q^2>1 GeV^2 **W^2>5 GeV^2**

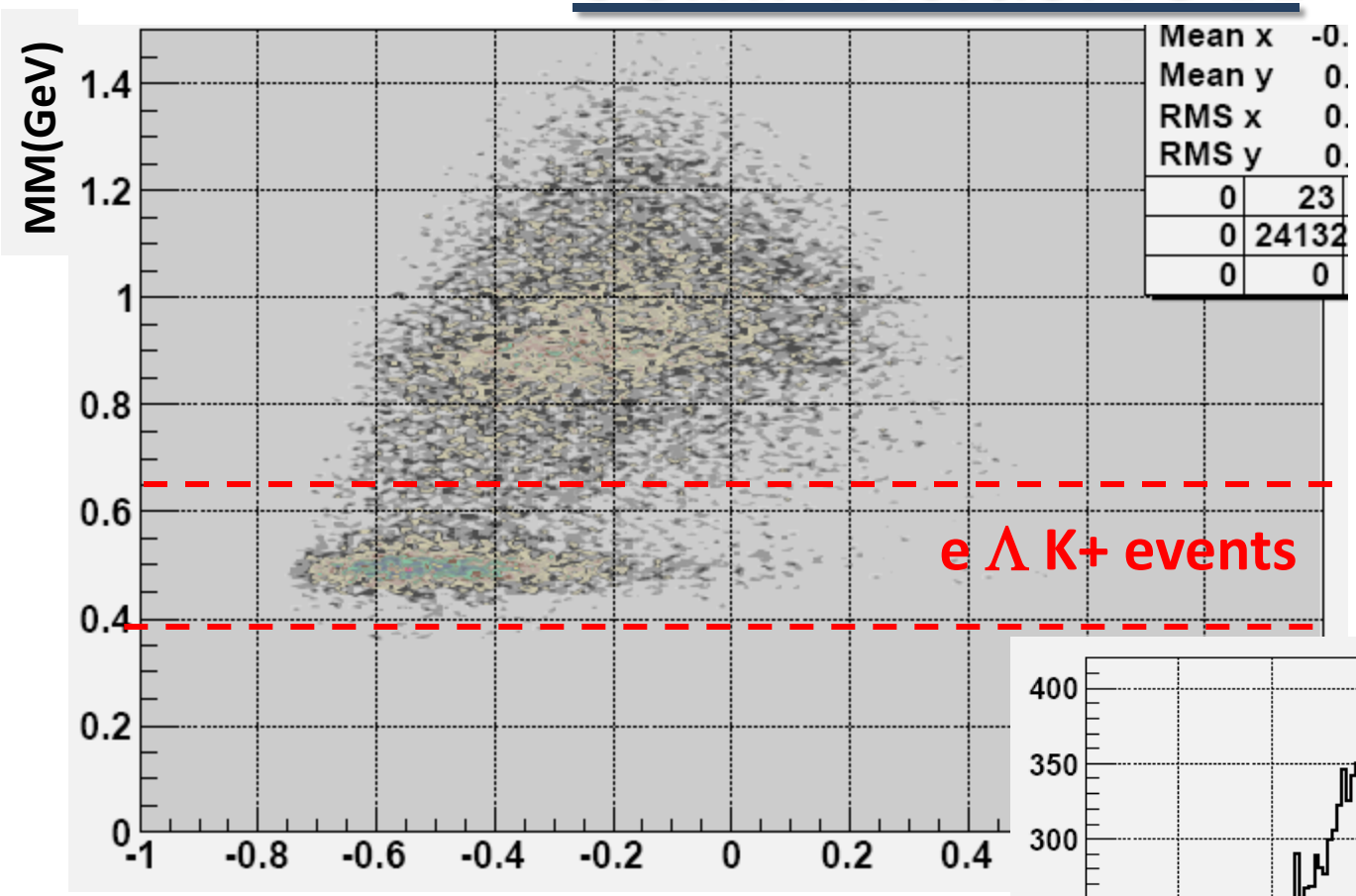
Λ Identification

$$\vec{e}p \rightarrow e'\Lambda X$$
$$\hookrightarrow p\pi^-$$





Semi-inclusive Λ



$$x_F = \frac{2p_l}{W} \rightarrow \cos\left(\theta_\Lambda^{CM}\right)$$

$x_F > 0$ <u>current fragmentation</u>

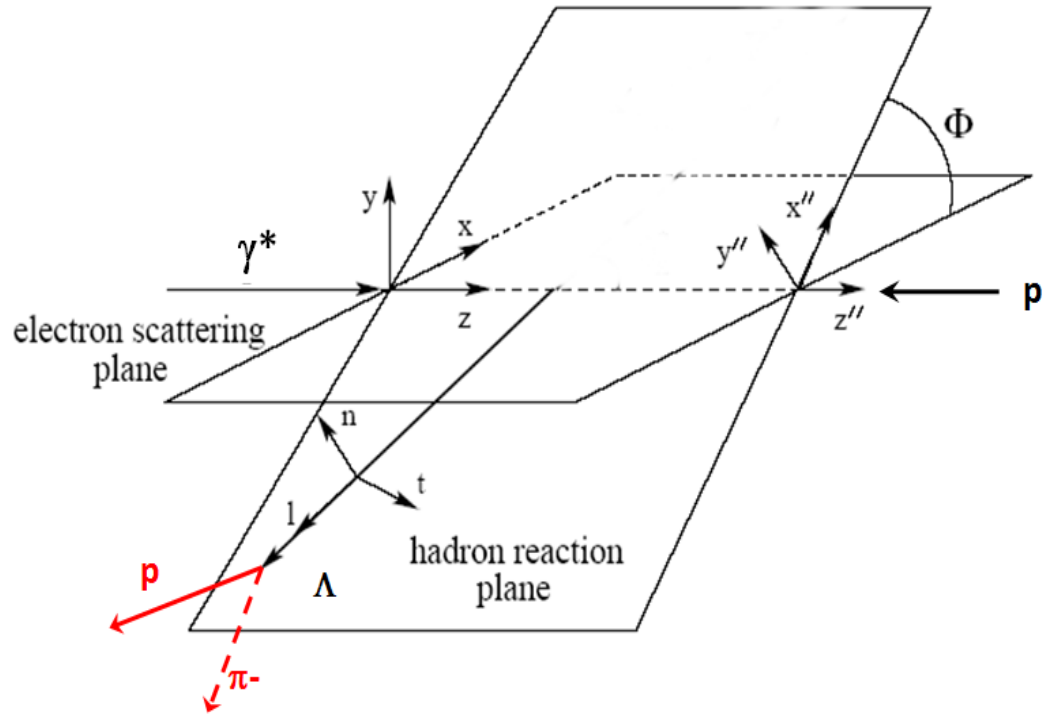
$x_F < 0$ <u>target fragmentation</u>

Polarization measurement

$$\frac{dN}{d\cos\vartheta_p^*} \propto 1 + \alpha P_\Lambda \cos\vartheta_p^*$$

$$P_\Lambda = \lambda P_\Lambda^T + P_\Lambda^I$$

$\lambda = \pm 1$



Reference frame is (x,y,z)

θ_p = proton angle with respect to:

$x \rightarrow P_x$

$y \rightarrow P_y$

$z \rightarrow P_z$

Polarization extraction

- **Beam Spin Asymmetry**

$$A(\cos\vartheta_p^*) = \frac{N_\Lambda^+ - N_\Lambda^-}{N_\Lambda^+ + N_\Lambda^-} \propto P_\Lambda^T \cos\vartheta_p^*$$

- **Unbinned likelyhood fit**

$$pdf \propto 1 + \alpha P_\Lambda \cos\vartheta_p^*$$

Preliminary results of long. polarization transfer with unbinned likelyhood fit

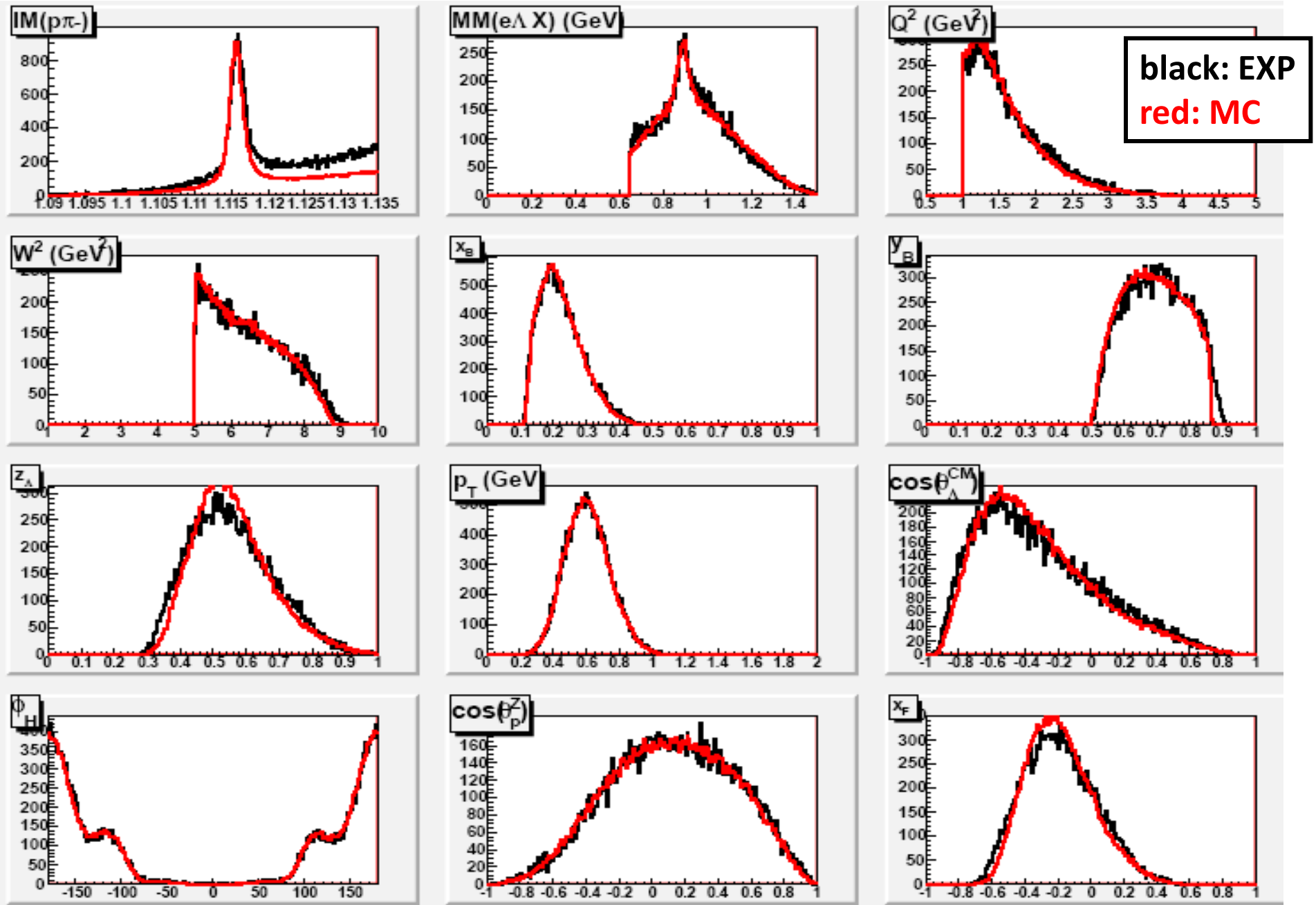
Monte Carlo simulation

- Event generator based on Pythia-JETSET
  - adjustment needed for JETSET parameters to reproduce Λ production in the target fragmentation
  - events are unpolarized

- Full simulation of the CLAS response with GEANT-based code

- Analysis of simulated data as for the experimental ones
  - about 100k SIDIS Λ have been reconstructed (12k in exp. data)

Comparison MC/EXP data



Λ polarization

From general consideration, for a spin1/2 baryon in SIDIS

$$P_\Lambda^x = \lambda\left[D_0^x + D_{\cos}^x \cos\phi\right] + \left[C_{\sin}^x \sin\phi + C_{\sin 2}^x \sin 2\phi\right]$$

$$P_\Lambda^y = \lambda\left[D_{\sin}^y \sin\phi\right] + \left[C_0^y + C_{\cos}^y \cos\phi + C_{\cos 2}^y \cos 2\phi\right]$$

$$P_\Lambda^z = \lambda\left[D_0^z + D_{\cos}^z \cos\phi\right] + \left[C_{\sin}^z \sin\phi + C_{\sin 2}^z \sin 2\phi\right]$$

$\lambda = \pm 1$

Transferred Polarization **Induced Polarization**

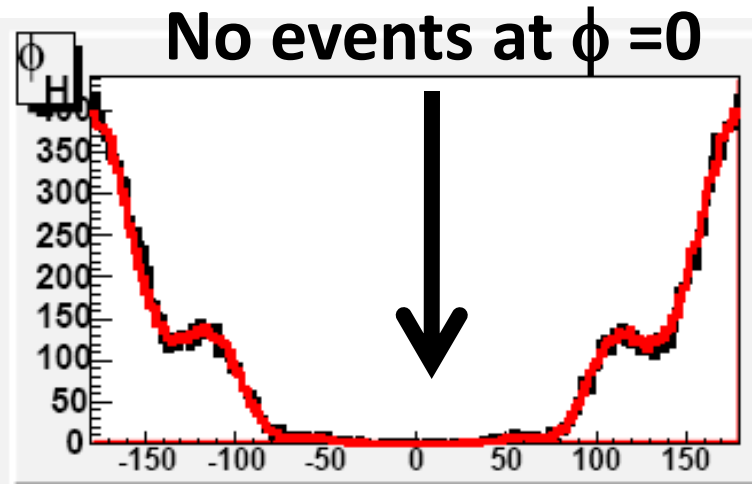
ϕ integration ⇒

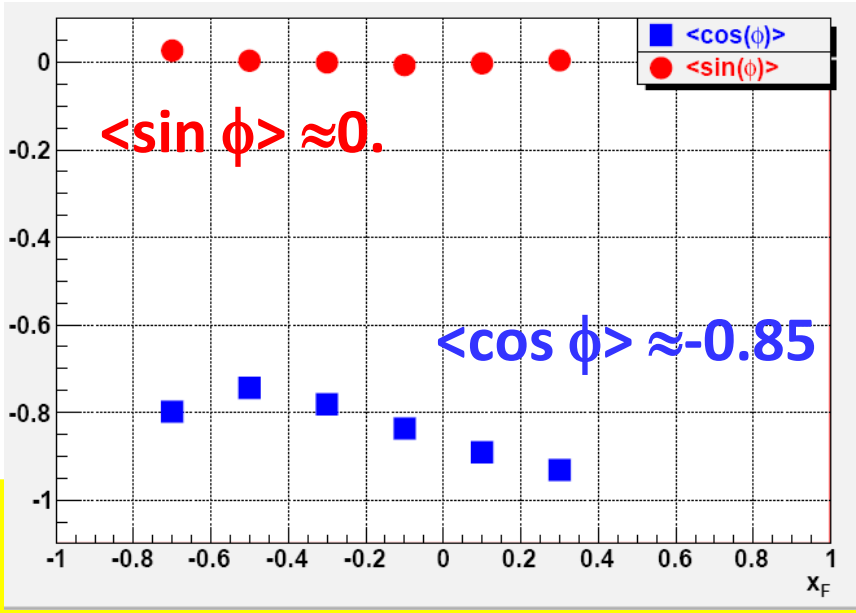
$$\begin{cases} P_\Lambda^x = \lambda D_0^x \\ P_\Lambda^y = C_0^y \\ P_\Lambda^z = \lambda D_0^z \end{cases}$$

- **Polarization transfer is in the scattering plane**
- **Unpolarized beam can produce transverse polarization only**

But acceptance effects can be important

CLAS sensitivity to ϕ harmonics





Longitudinal polarization transfer

$$P_{\Lambda}^{T,z} = D_0^z + D_{\cos}^z \cos(\phi)$$

In the CLAS acceptance

$$P_{\Lambda}^{T,z} = D_0^z + D_{\cos}^z \langle \cos(\phi) \rangle \approx D_0^z - 0.85 D_{\cos}^z$$

The two parameters are highly correlated

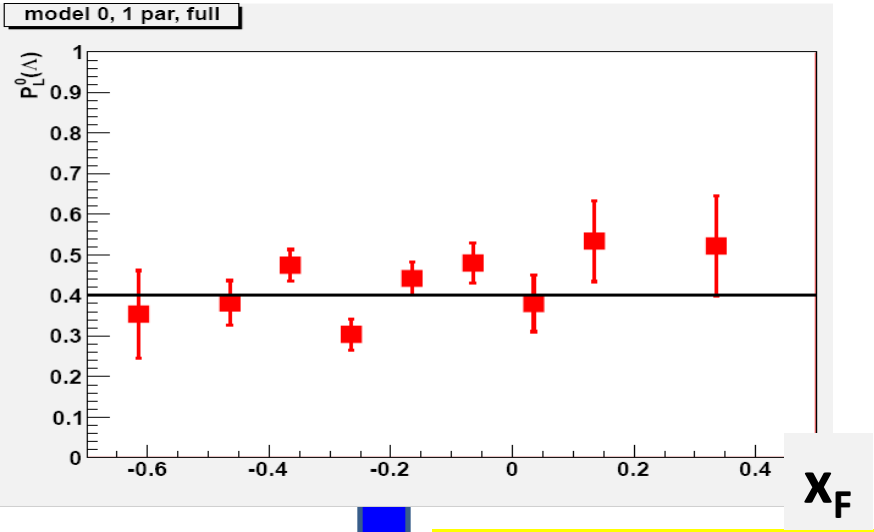
>80% correlation from the fits

If $D_0^z \approx D_{\cos}^z$ → **we measure ≈<u>zero</u>**

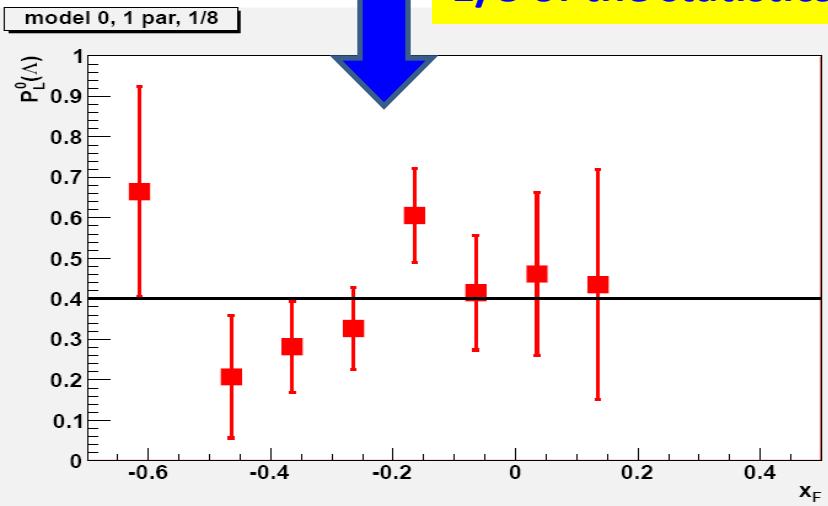
Monte Carlo test

MC (unpolarized) data with some "model" for the Λ long. pol. transfer

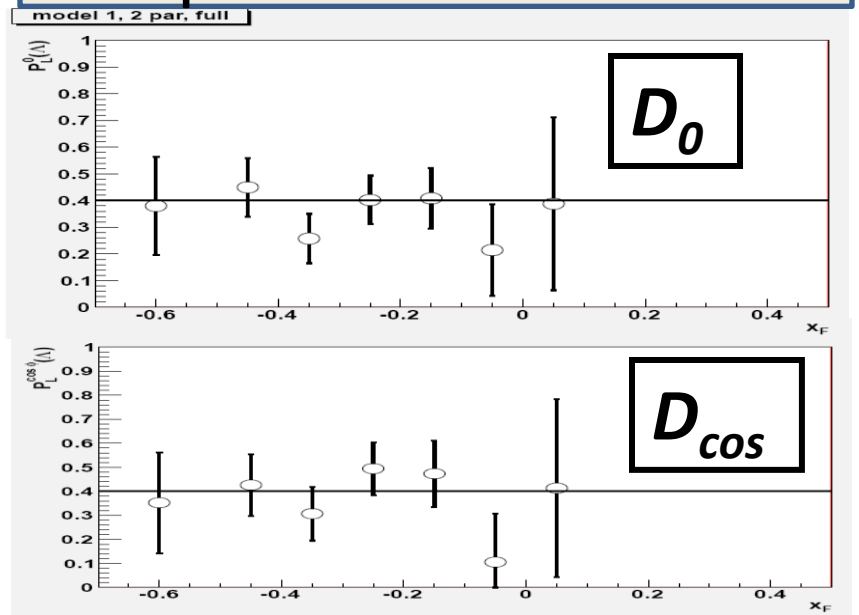
"model 1" $D_0^z = 0.4$ $D_{\cos}^z = 0.$
1 free parameter fit

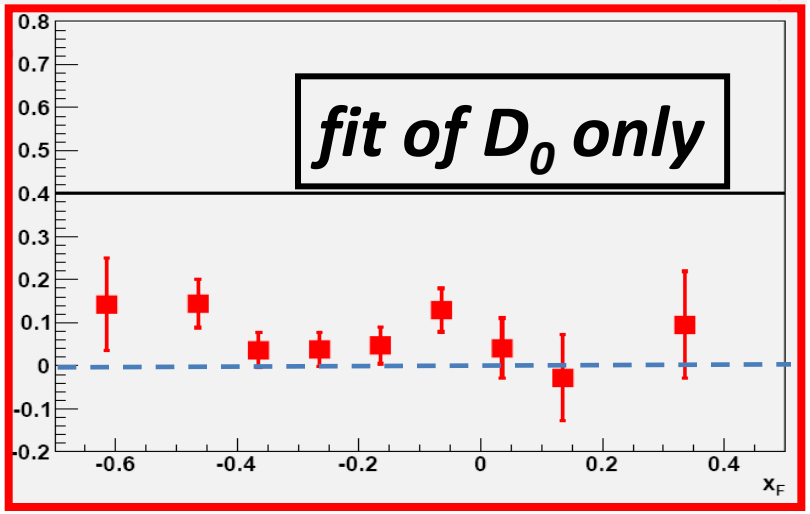


1/8 of the statistics



"model 2" $D_0^z = 0.4$ $D_{\cos}^z = 0.4$
2 free parameter fit





Fit results for experimental data

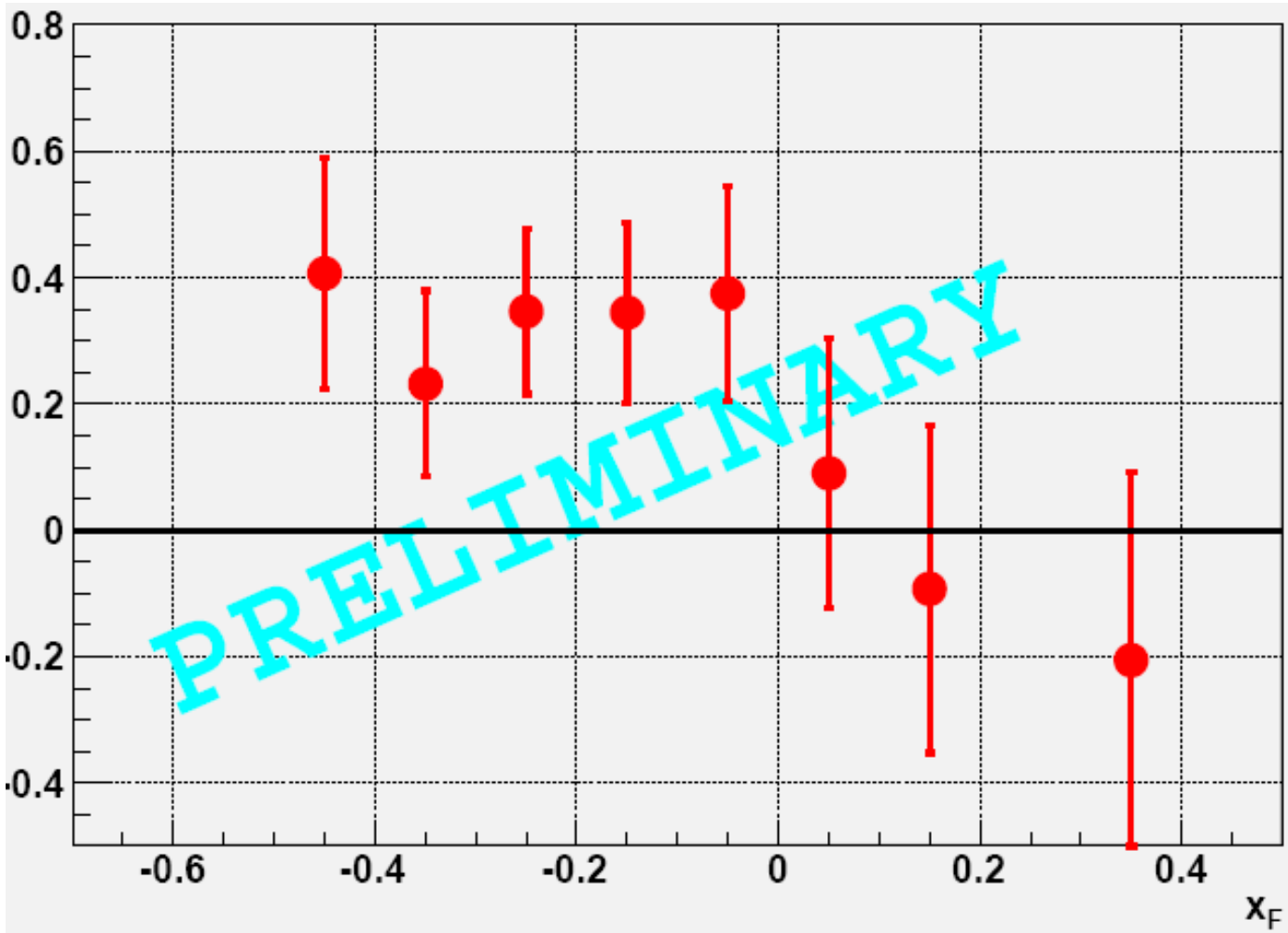
Longitudinal polarization transfer
Unbinned fit with 1 free parameter vs x_F

$$P_{\Lambda}^{T,z} = D_0^z + D_{\cos}^z \langle \cos(\phi) \rangle_{CLAS}$$

$x_F < 0$
$P_{\Lambda}^{measured} \sim 0.3$

$$\Rightarrow D_0^z \neq D_{\cos}^z$$

$x_F > 0$
$P_{\Lambda}^{measured} \sim 0.$



Outlook

To finalize the analysis:

1) **Study kinematic dependencies**
   - Q^2, p_T, MM dependencies in the target and current fragmentation regions
   - double binning?

2) **Analysis of P_x and P_y**
   - additional $\cos 2\phi$ modulation in the transverse polarization

3) **Study of systematic uncertainties**

backup slides

Unbinned likelyhood fit

$$L=\prod_{i=1}^{n} f^{norm}(X_i,\alpha)=\prod_{i=1}^{n}\frac{f(X_i,\alpha)}{N}=\frac{\prod_{i=1}^{n} f(X_i,\alpha)}{(N_+)^{n_+}(N_-)^{n_-}}$$

n=number of events
X = set of kinematic variables
α = set of parameters to be determined
f(X, α) = probability distribution function
N = normalization factor of the PDF
↑↓ = polarization states

Probability distribution function:

$$f^{\uparrow,\downarrow}=1+\alpha_w P_\Lambda^{\pm}\cos\vartheta_p$$

$$P_\Lambda^{\pm}=P_\Lambda^{I}\pm P_\Lambda^{T}$$

The coefficients of all the ϕ harmonics in P_Λ can be fitted at the same time

Prescription for the normalization without MC data:

sum over the two helicities

$$N^{\uparrow,\downarrow}=\sum_{i=1}^{n^{\uparrow}+n^{\downarrow}}\left(1\pm\alpha_w P_\Lambda^{\pm}\cos\vartheta_p\right)$$

Background subtraction

Good events selected within some kinematic cut contain background

$$L=\prod_{i=1}^{n}\frac{f(X_i,\alpha)}{N}=\underbrace{\left[\prod_{i=1}^{n_S}\frac{f(X_i,\alpha)}{N}\right]}_{\text{SIGNAL}}\underbrace{\left[\prod_{i=1}^{n_B}\frac{f(X_i,\alpha)}{N}\right]}_{\text{BACKGROUND}}$$

To subtract the BKG contribution in the selected events, add n_B background events taken from outside the signal region with weight -1

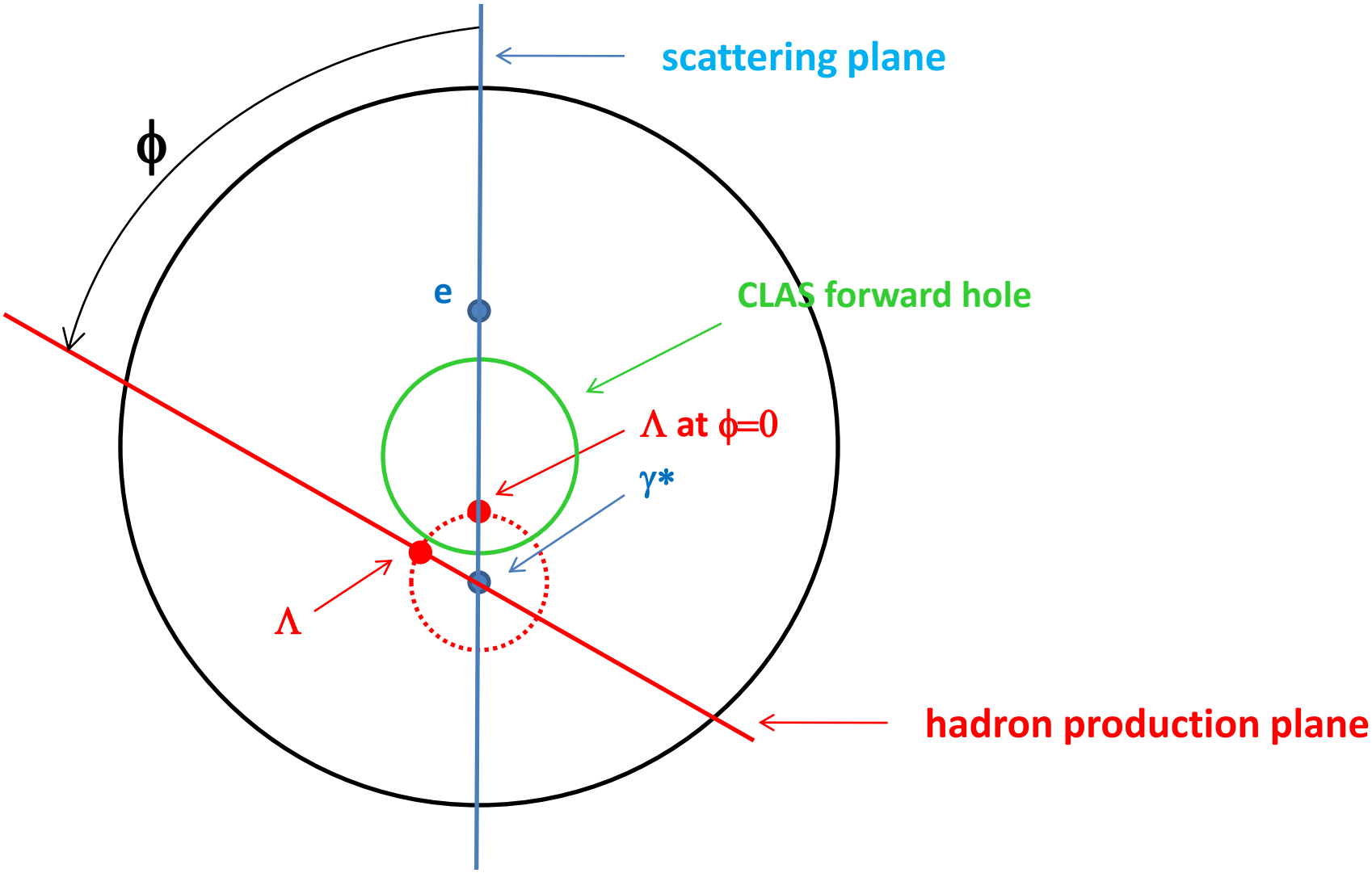
$$L=\prod_{i=1}^{n}\frac{f(X_i,\alpha)}{N}=\left[\prod_{i=1}^{n_S}\frac{f(X_i,\alpha)}{N}\right]\left[\prod_{i=1}^{n_B}\frac{f(X_i,\alpha)}{N}\right]\boxed{\left[\prod_{i=1}^{n_B}\frac{f(X_i,\alpha)}{N}\right]^{-1}}$$

Events from the side-band region

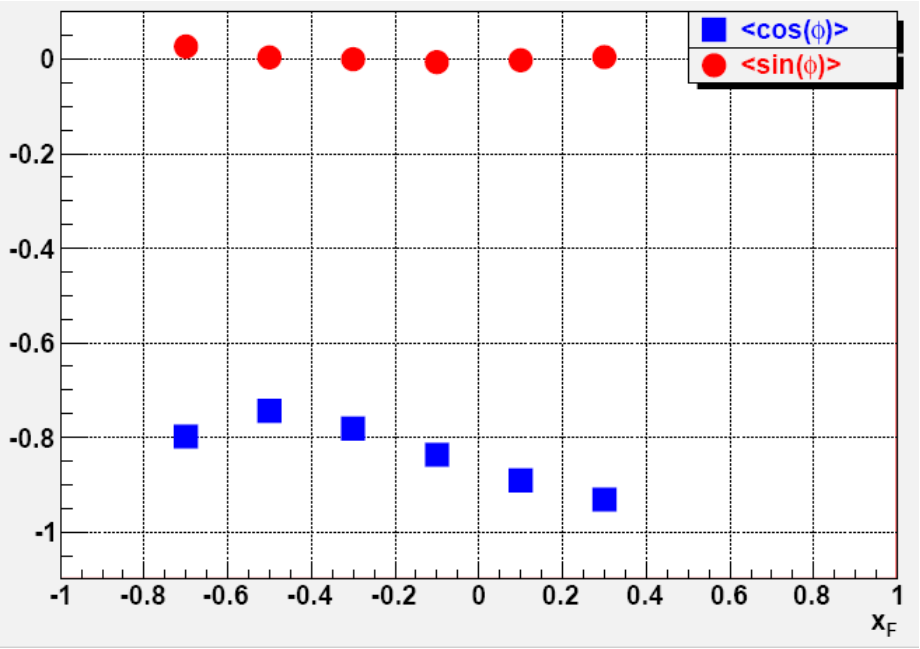
The total number of events for the fit is now $n+n_B$

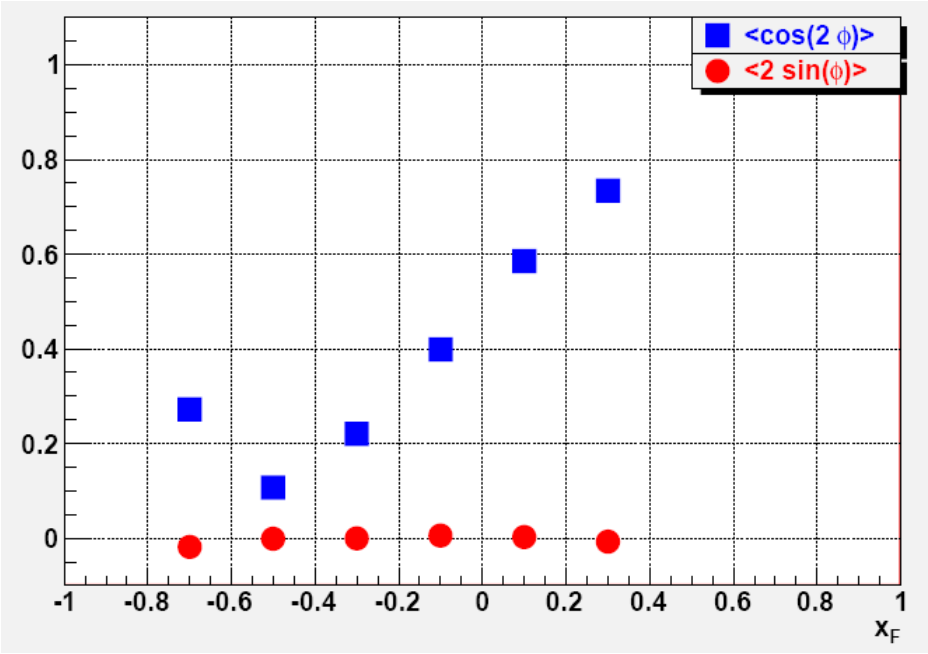
peak events: $w_i=+1$

side band events: $w_i=-1$


scattering plane
ϕ
e
CLAS forward hole
Λ at ϕ=0
γ*
Λ
hadron production plane

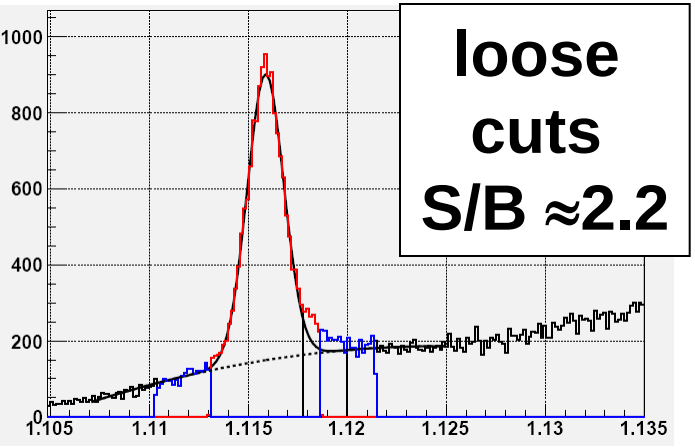
ϕ averages in CLAS

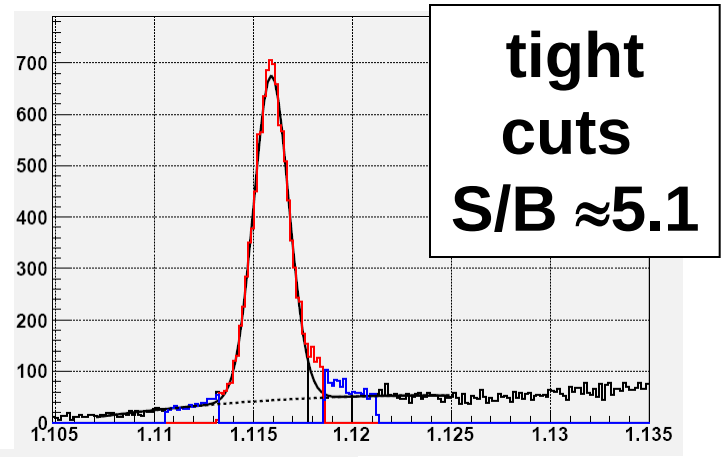


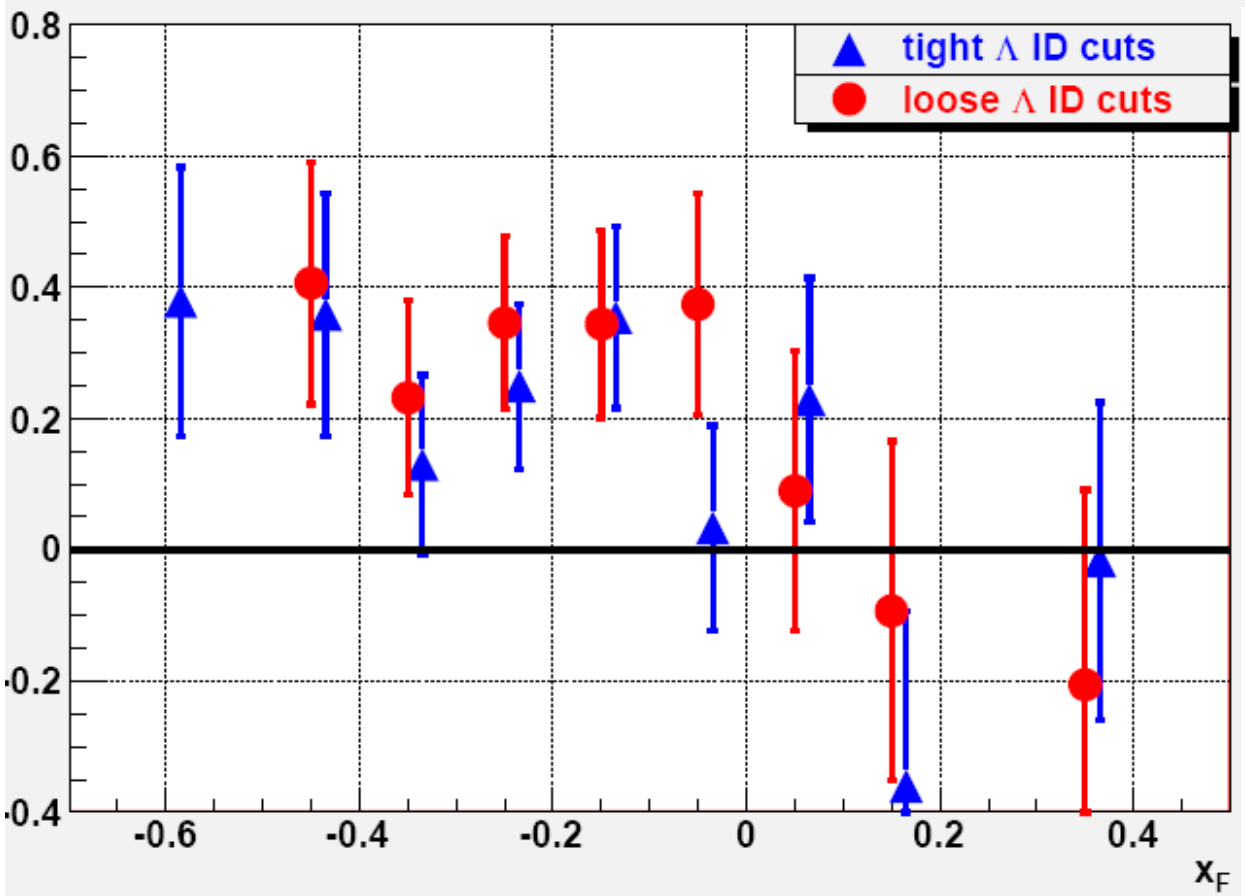


Only even ϕ-harmonics are accessible

Λ ID cuts


loose cuts
S/B ≈2.2
1000
800
600
400
200
0
1.105
1.11
1.115
1.12
1.125
1.13
1.135

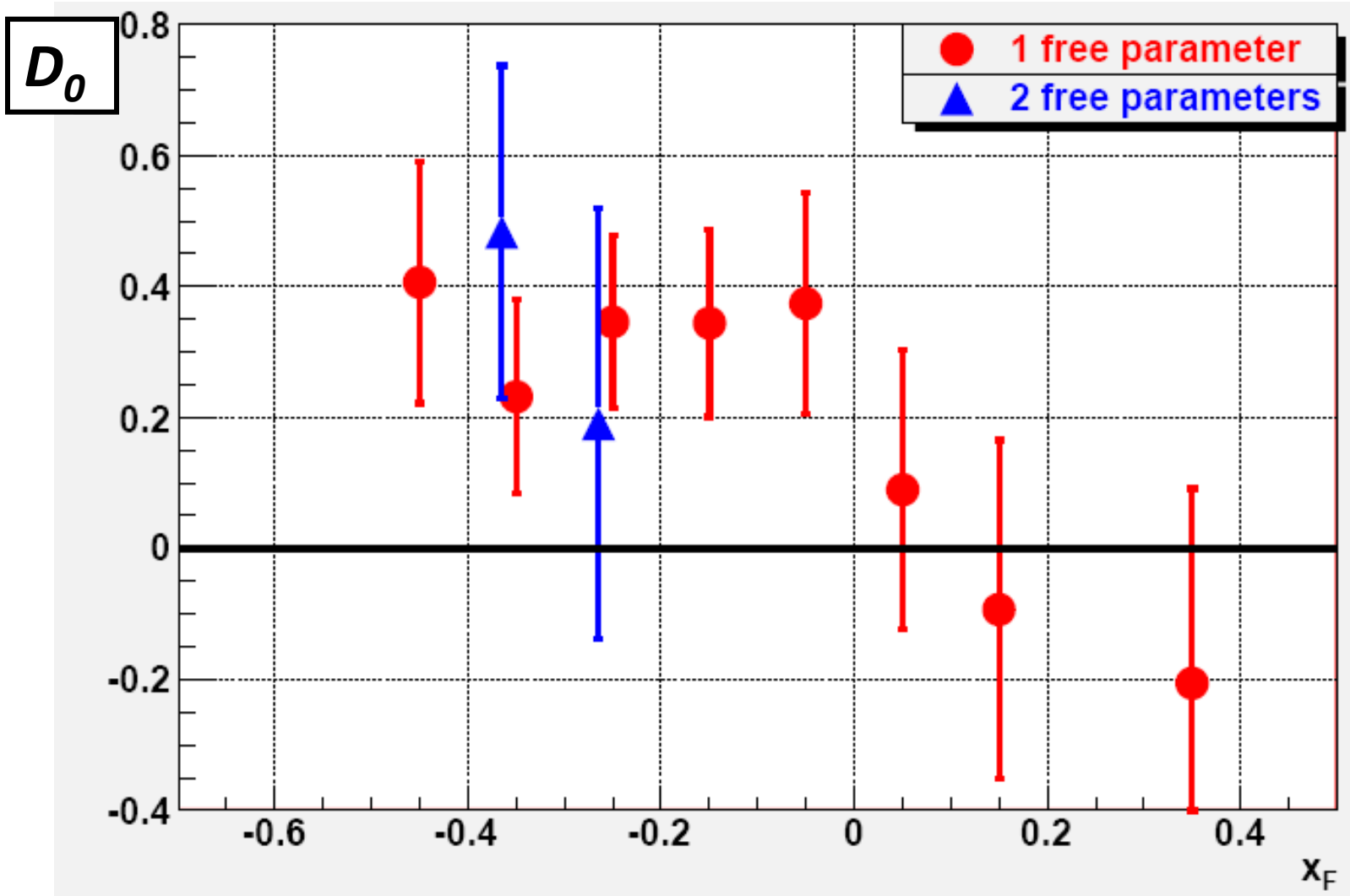

tight cuts
S/B ≈5.1
700
600
500
400
300
200
100
0
1.105
1.11
1.115
1.12
1.125
1.13
1.135


tight Λ ID cuts
loose Λ ID cuts
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.4
-0.2
0
0.2
0.4
x_F

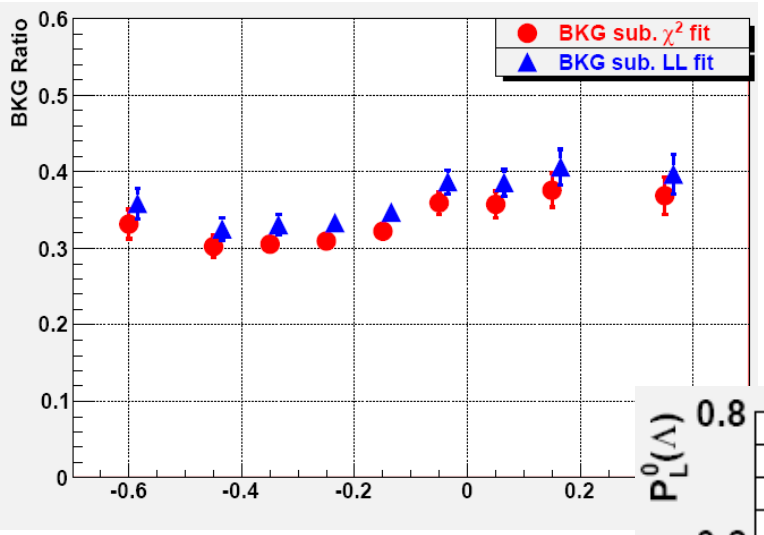
Results with 2 free parameters

$$P_{\Lambda}^{T} = P_{\Lambda}^{0} + P_{\Lambda}^{\cos\phi}\cos(\phi)$$

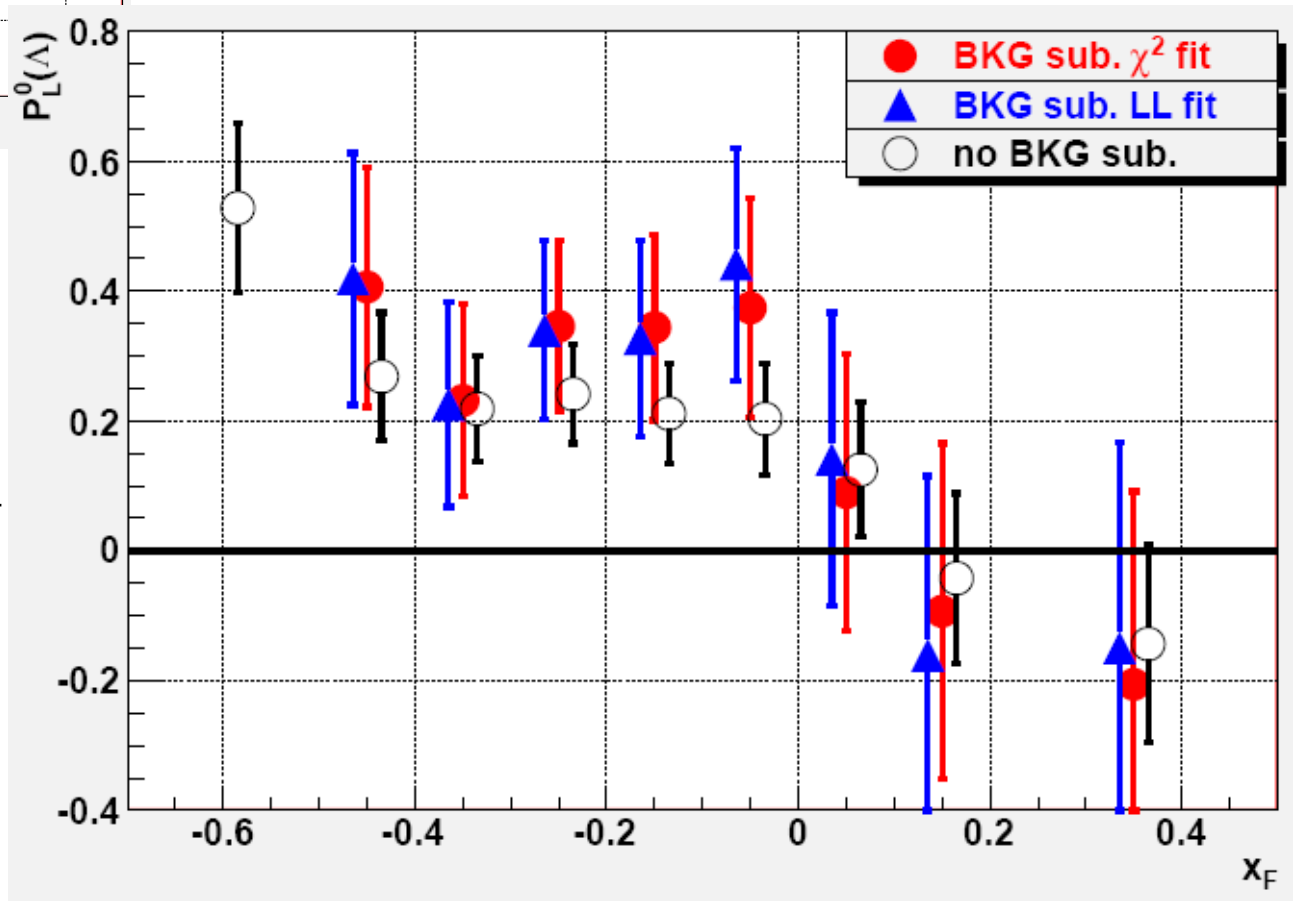
No convergence for almost all x_F bins



Background subtraction



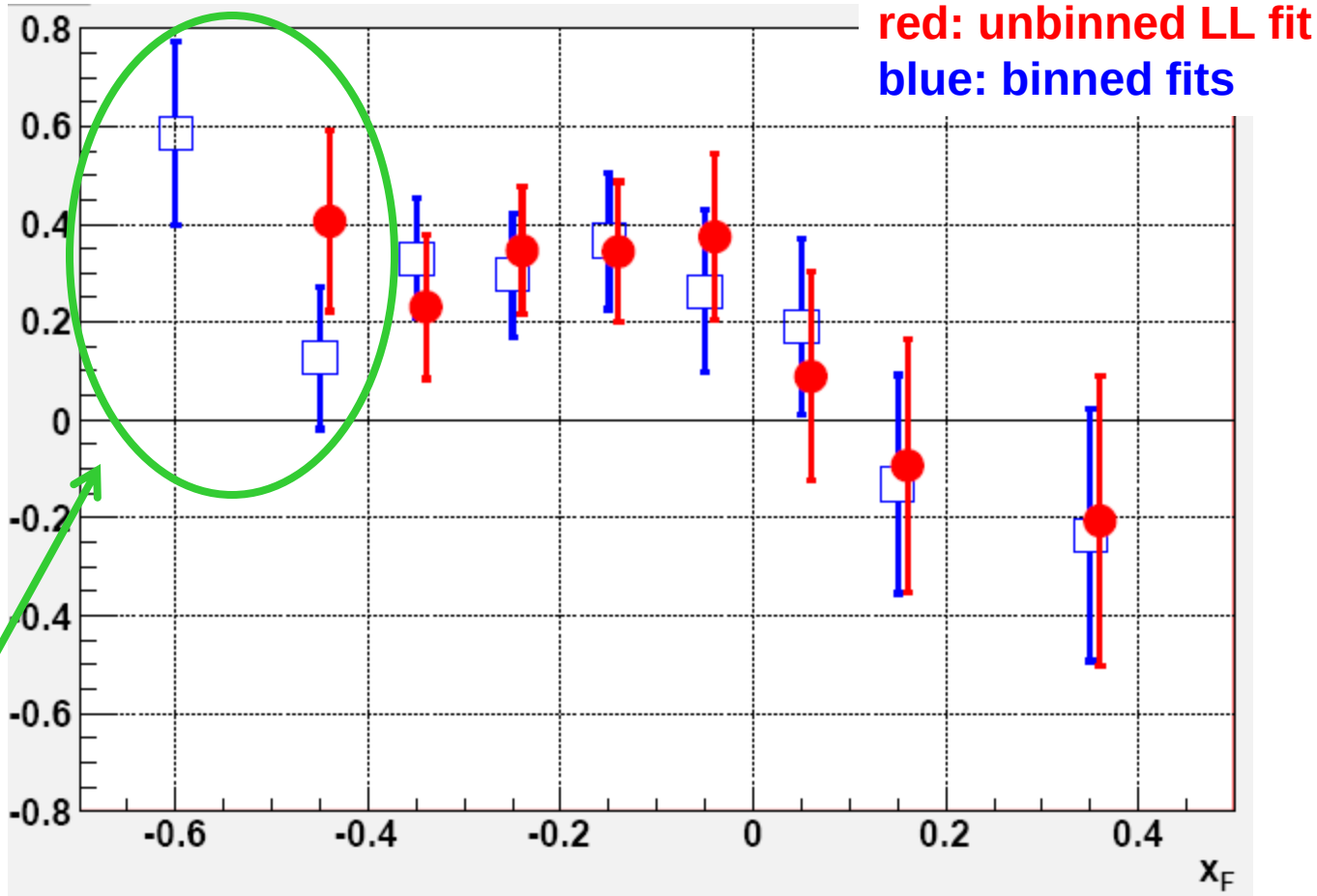
small difference in the number of side-band events to be included in the fit



If no BKG subtraction

$$P_{\Lambda}^{measured} = P_{\Lambda} \frac{N_{\Lambda}}{N_{\Lambda} + N_{BKG}}$$

Comparison with binned analysis



where the statistics is too low, the LL fit gives better results or doesn't converge