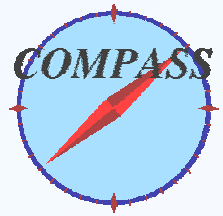
FIRST PHYSICS FROM COMPASS

Franco Bradamante

University of Trieste and INFN Trieste

on behalf of the
COMPASS Collaboration

Bloomington Indiana, May 28



- INTRODUCTION
- SPECTROMETER AND DATA TAKING
- FIRST PHYSICS RESULTS (run 2002)
  - A_1^d
  - Transversity
  - A_{LL} from high p_T
- OTHER ONGOING ANALYSIS
  - A_{LL} from open charm
  - Λ physics
  - Exclusive ρ and ϕ, J/Ψ
  - Flavour separation
- SUMMARY AND OUTLOOK

COmmon Muon and Proton Apparatus for Structure and Spectroscopy

NA58

Finland, France, Germany, India, Israel, Italy, Japan,
Poland, Portugal, Russia, Switzerland

Bielefeld, Bochum, Bonn, Burdwan, Calcutta, CERN,
Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon,
Mainz, Miyazaky, Moscow, Munich, Nagoya, Protvino,
Saclay, Tel Aviv, Torino, Trieste, Warsaw

28 Institutes, more than 200 physicists

THE COMPASS EXPERIMENT

- **experiment:**

thought of in	April ’94	Trento workshop
	Nov. ‘94	Trieste workshop
LoI	March ’95	
encouraged	June ‘95	SPSLC in Cogne
Proposal	March ’96	
recommended	Sept. ’96	
approved by RB	Feb. ‘97	as NA58
Technical run	2000	
Commissioning	2001	

- **since 2002 taking data**

with

a new spectrometer with outstanding performances

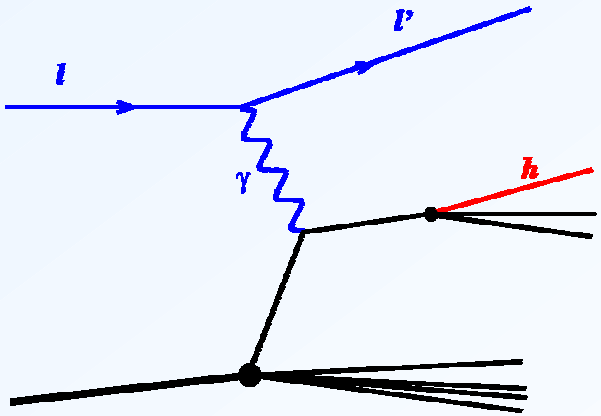
- **merging of two programmes:** **HMC** (muon beam) **CHEOPS** (hadron beam)

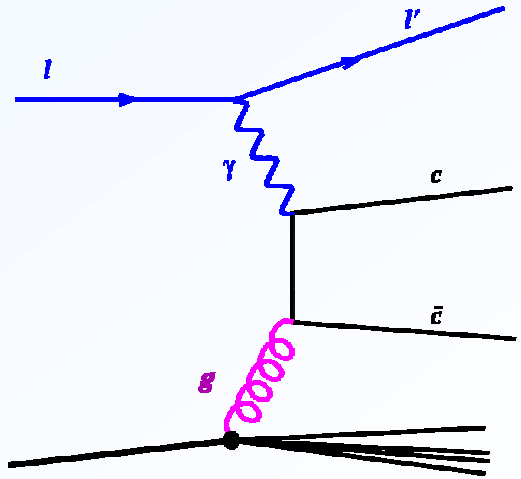
COMPASS programme with the muon beam

to determine the polarised parton density functions in a polarised nucleon from measurements of hadron asymmetries in semi-inclusive polarised DIS, both longitudinal and transverse

specifically,

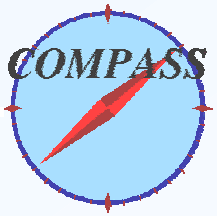
- to measure the gluon polarisation ΔG through open charm (Gluk and Reya, Altarelli and Stirling, 1988)





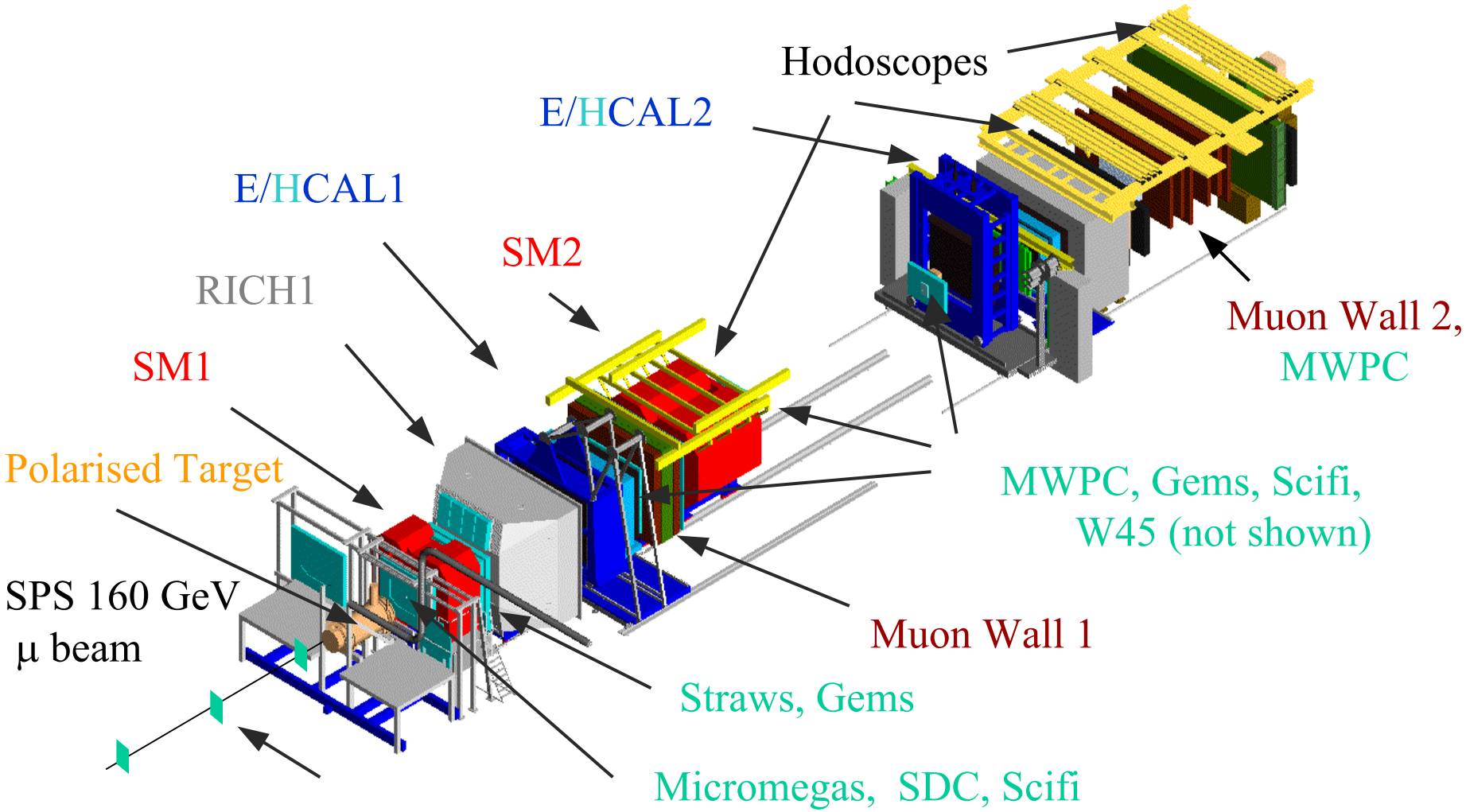
- to measure h_1, the new territory
- to measure the spin transfer in fragmentation from Λ production
- to remeasure with high statistics g_1 and g_2
- ……

COMPASS programme with hadron beams



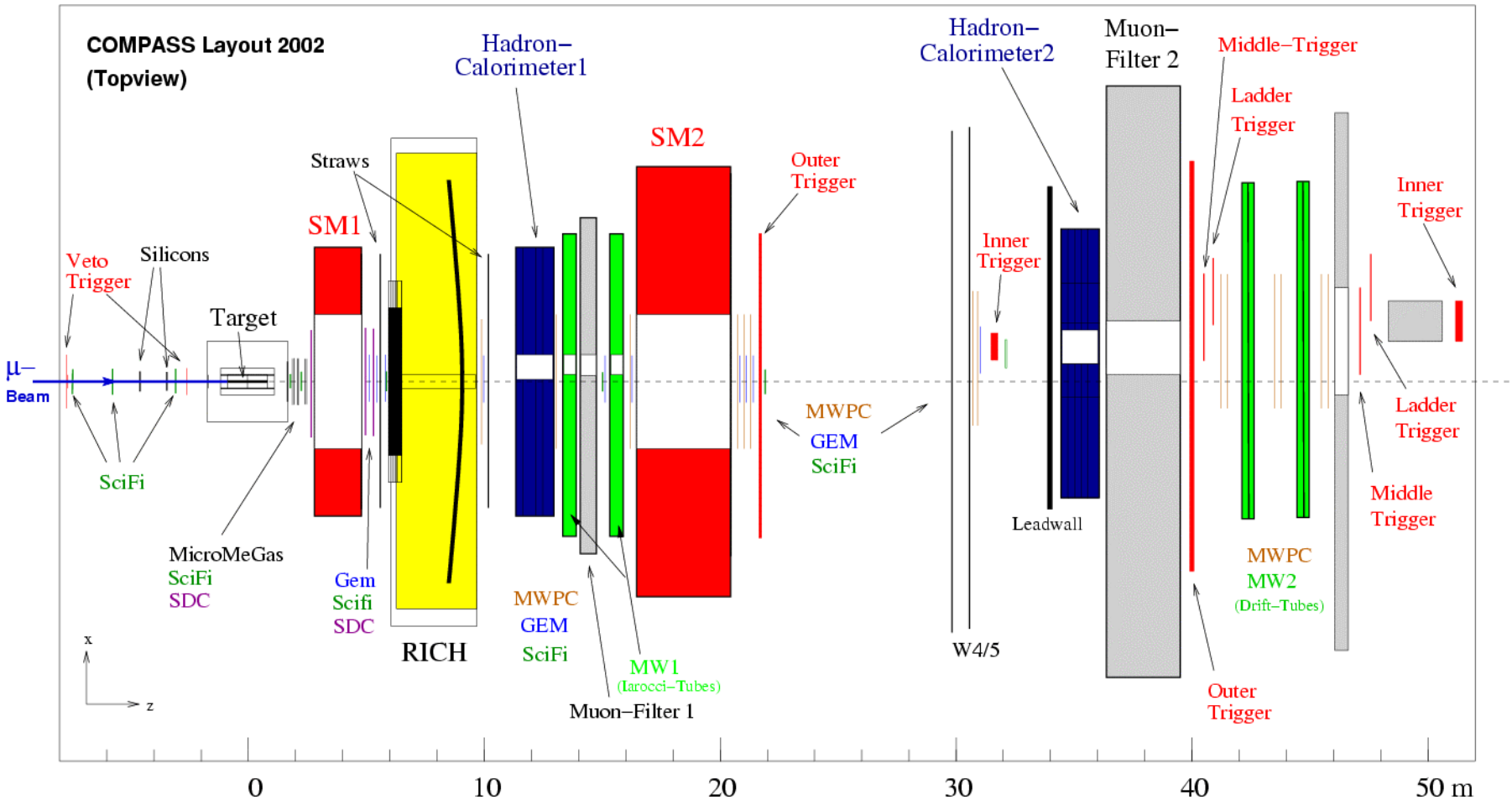
- **charmed hadrons**
  - production phenomena (p, π, K)
  - leptonic decays
  - semileptonic decays
  - precision measurements of c-baryon lifetimes
  - production and spectroscopy of cc-baryons
- **gluonic states**
  - search for glueballs in Pomeron-Pomeron scattering
  - search for exotic states
- **hadron structure**
  - polarizability in Primakoff reactions

THE COMPASS SPECTROMETER

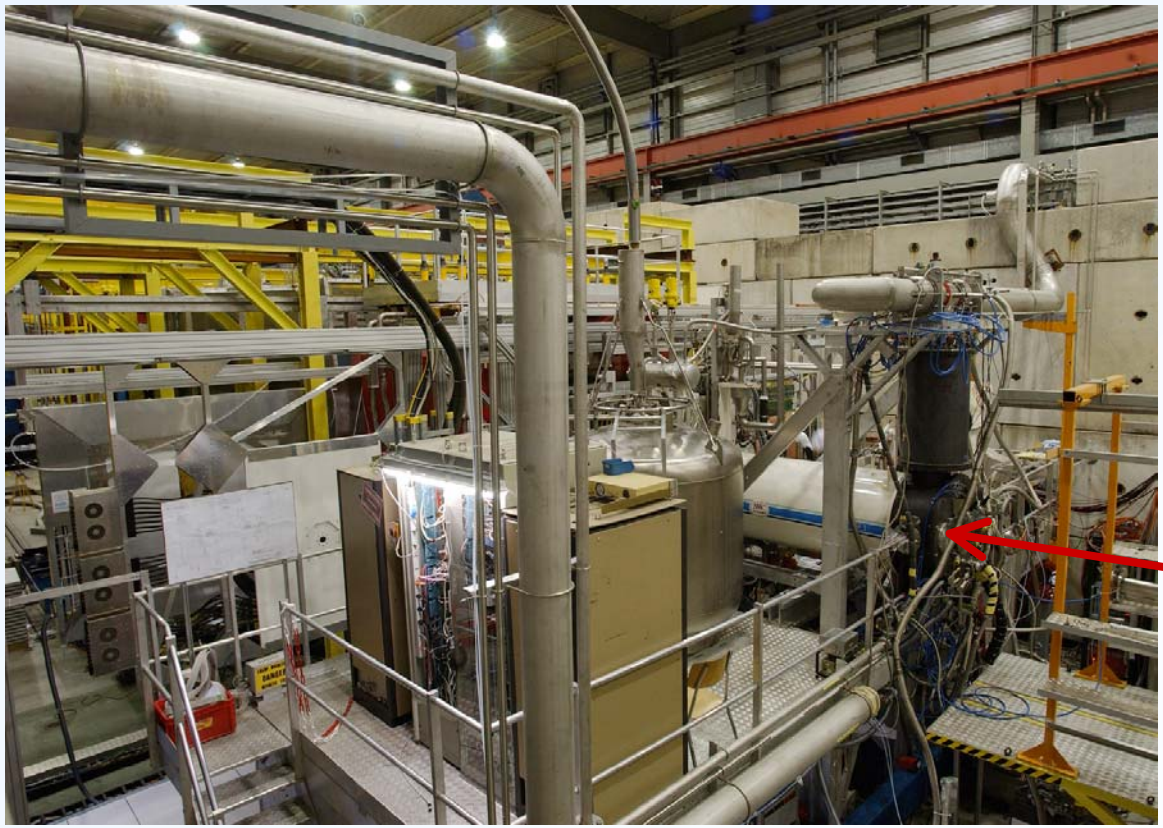


THE COMPASS SPECTROMETER

2002



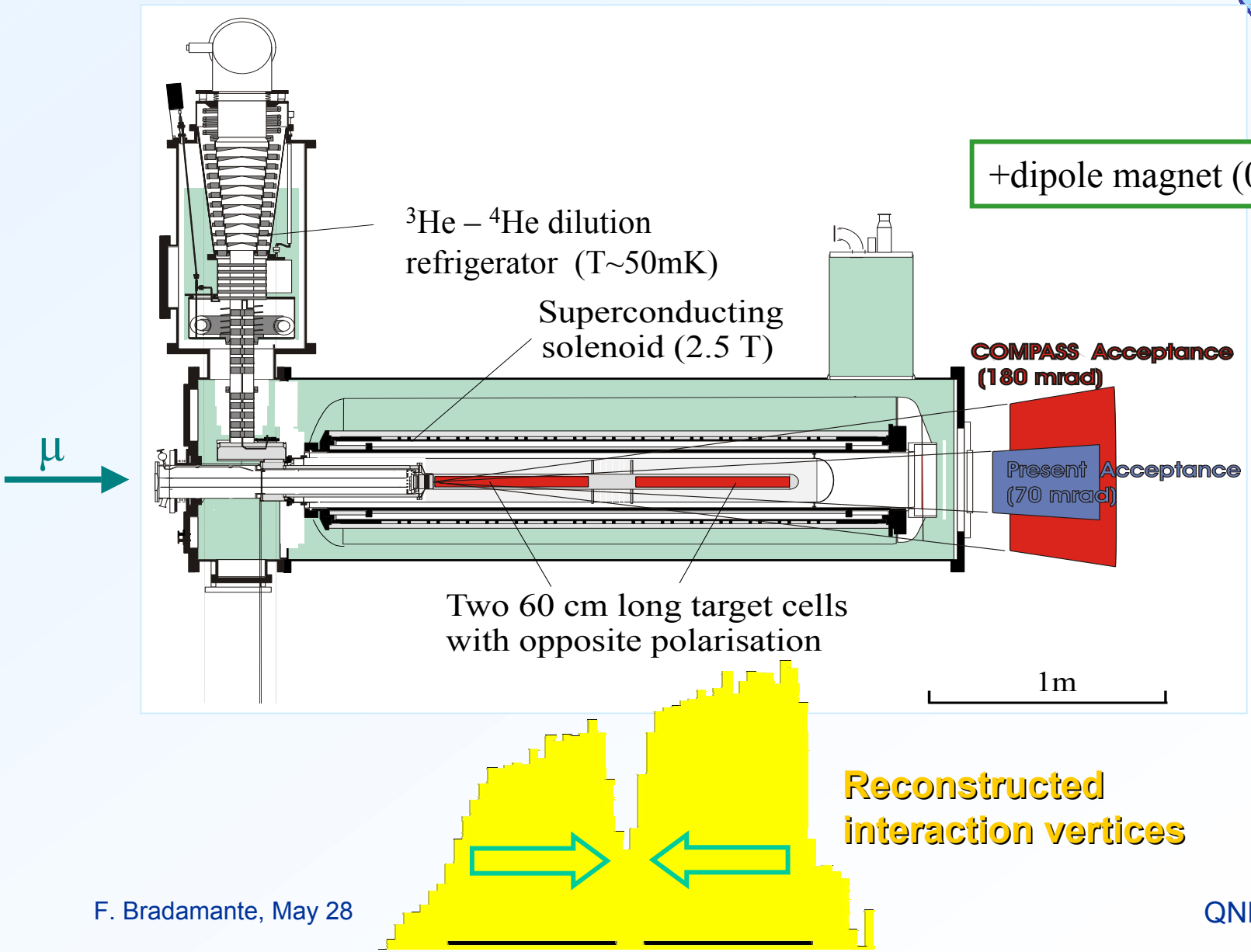
THE POLARISED TARGET



- ^{6}LiD
- ± 50 % polarisation
- 40 % dilution factor
- 2.5 T
- 50 mK

μ

THE TARGET SYSTEM

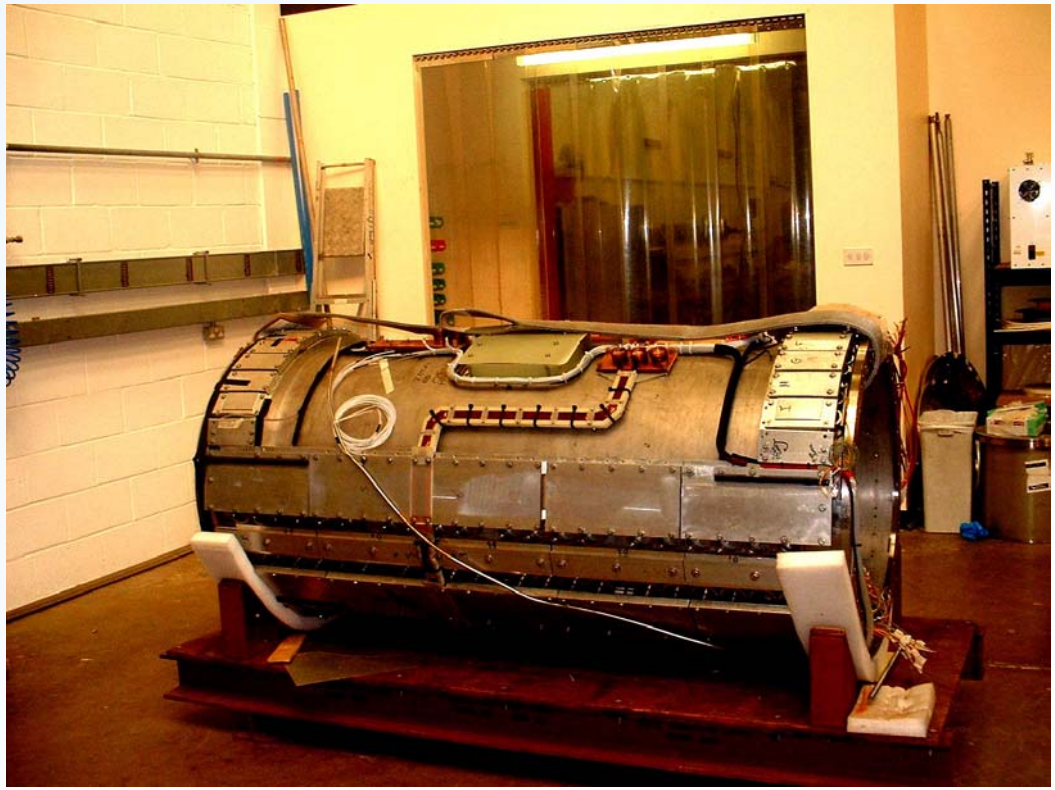


THE COMPASS/Oxford Danfysik MAGNET

MoU CERN/DAPNIA/COMPASS

signed december 2003 :

- finalize instrumentation, full magnetic tests



2004:

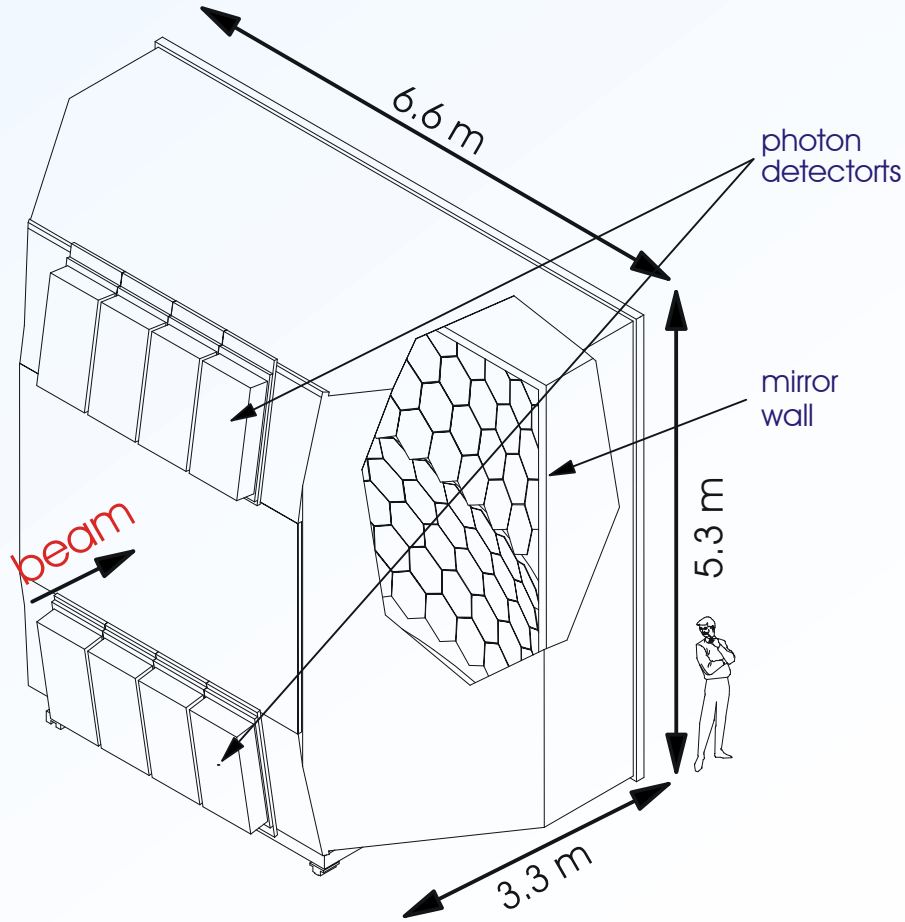
- delivery to Saclay
- vacuum tests, cooling, max field, reversal/homogeneity
- delivery to CERN

2005: installation, tests, magnetic measurements, polarization

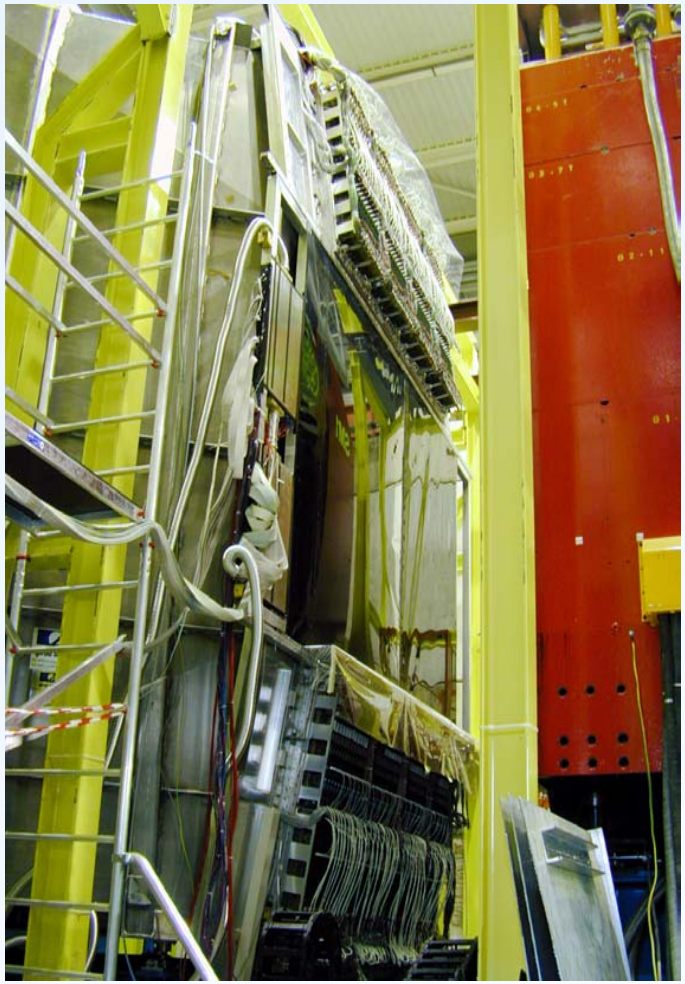
RICH1

Ring Imaging Cherenkov

- 90 m^3 (3 m C_4F_{10})
- 116 VUV mirrors (focal lenght 3.3 m)
- 5.3 m^2 UV detectors
  - MWPC CsI cathods
  - 8x8 mm^2 pad
- 84k analog r/o channels
- K/π separation up to ~40 GeV

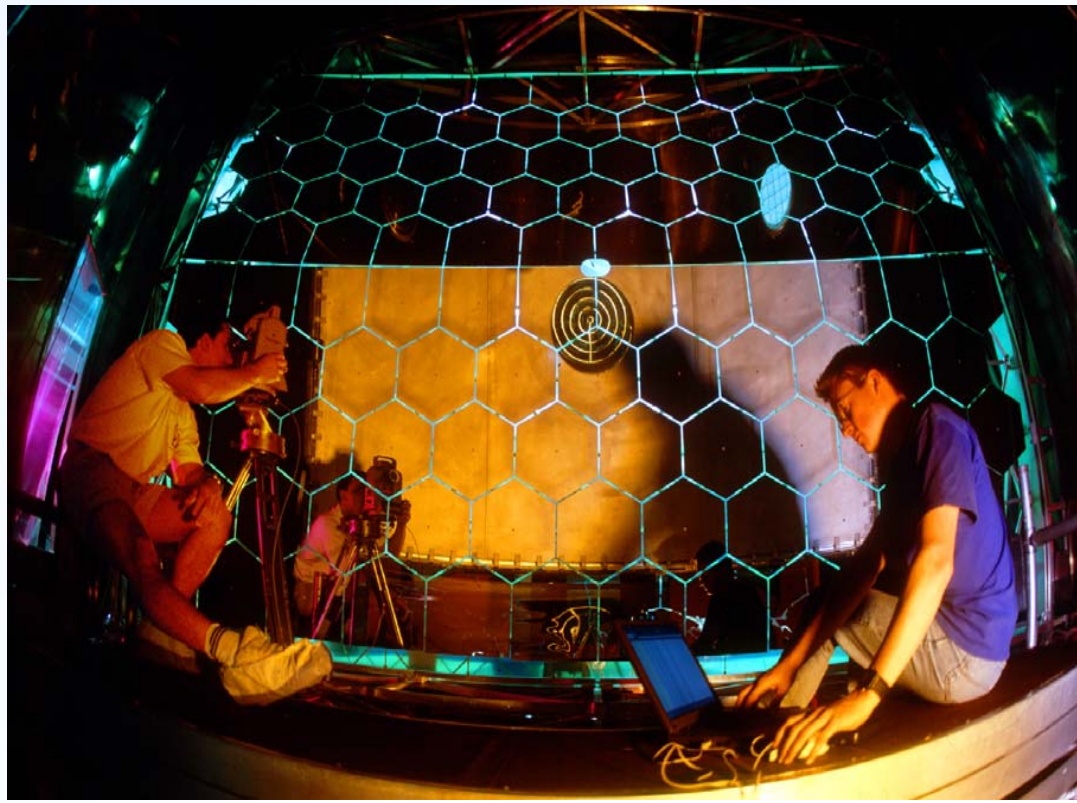


RICH1



PDs, 5.3 m^2

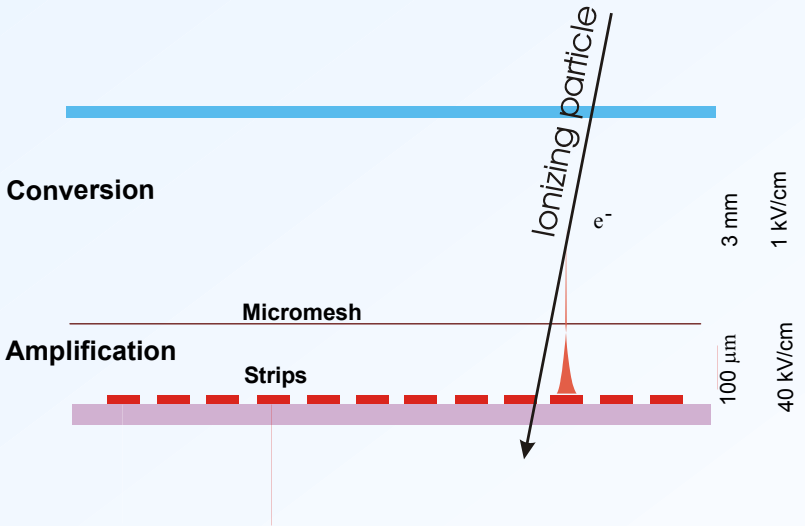
116mirrors, 20 m^2

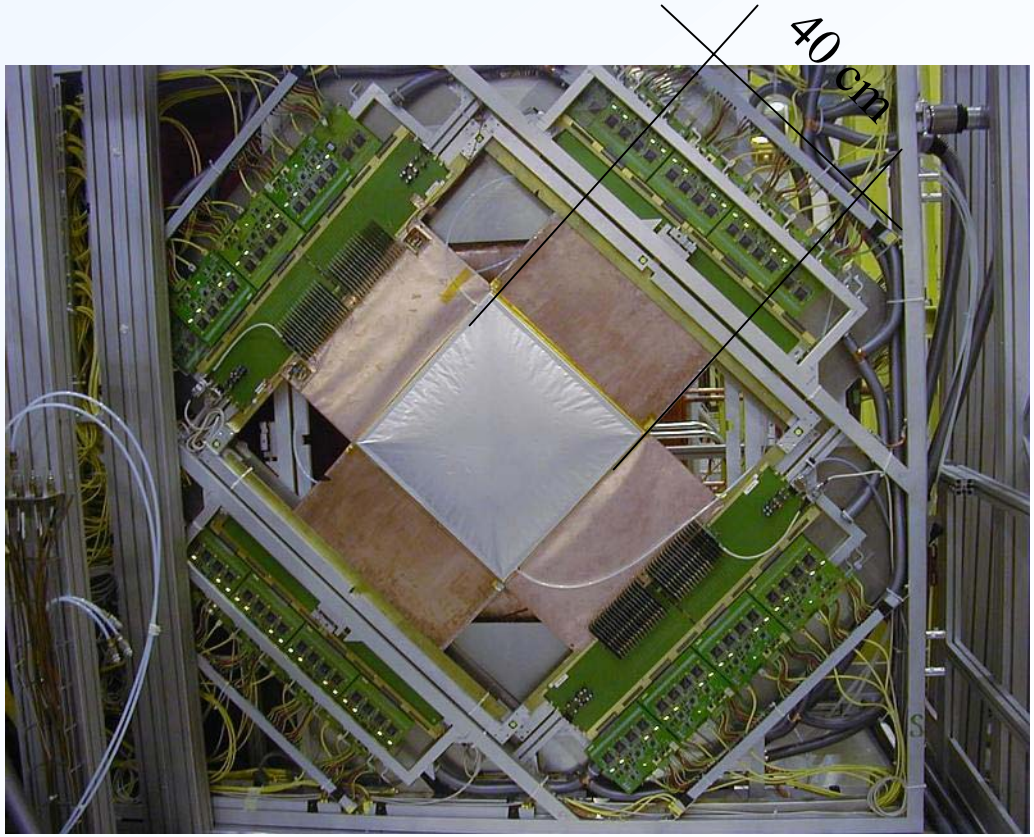


MicroMegas

Micro Mesh Gas Detectors

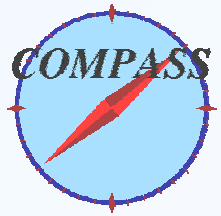
Novel gaseous detector





40x40 cm^2

2002 RUN



- 160 GeV/*c* muons, $2 \cdot 10^8$ μ^+/4 s every16.8 s, $P_{beam} \cong 80$ %
- ^{6}LiD target, $P_{target} \cong 50$ %
- polarization reversal by magnet field rotation every 8 h

- 200 k readout channels, 35-40 kB/event
- data taking:
  - 24 days setup (about 2/3 of equipment new)
  - 57 days longitudinal target polarisation
  - 19 days transverse target polarisation

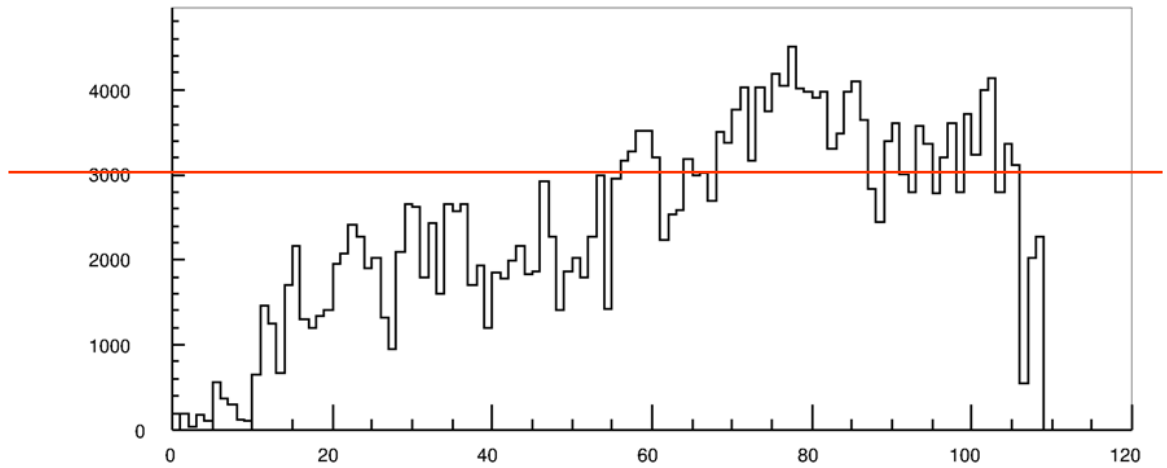
- 5 billion events recorded, 260 TByte total

- similar statistics in 2003

Central Data Recording

Design value: 35MB/s

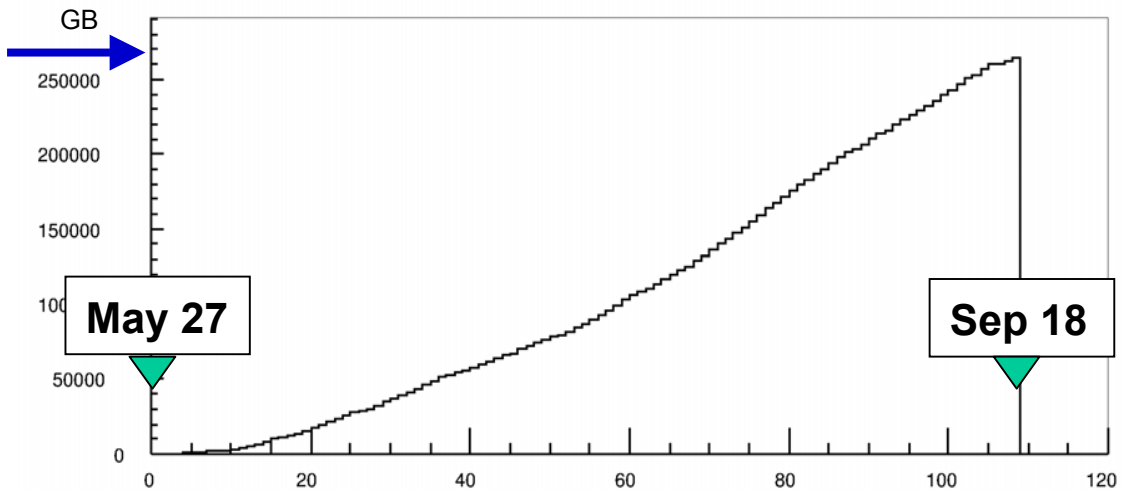
3TB/day



2002

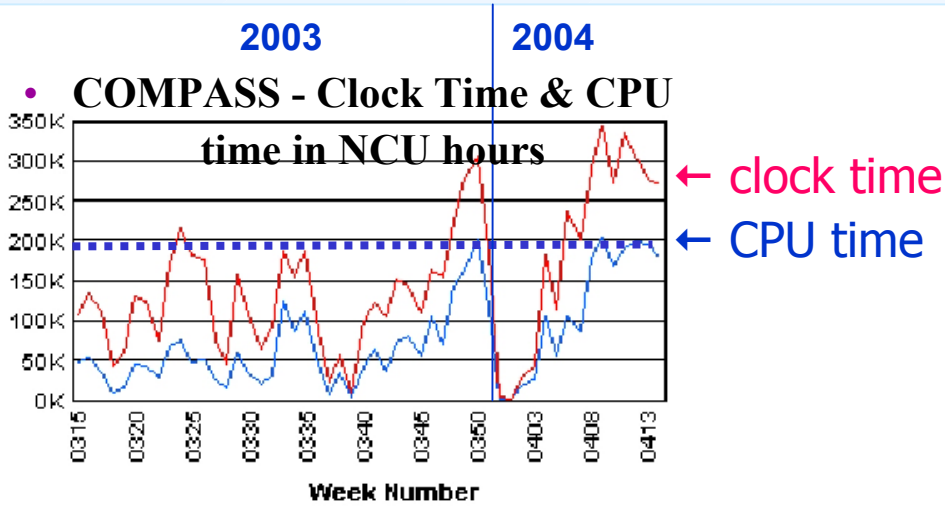
260 TByte in ~100 days

5 billion events



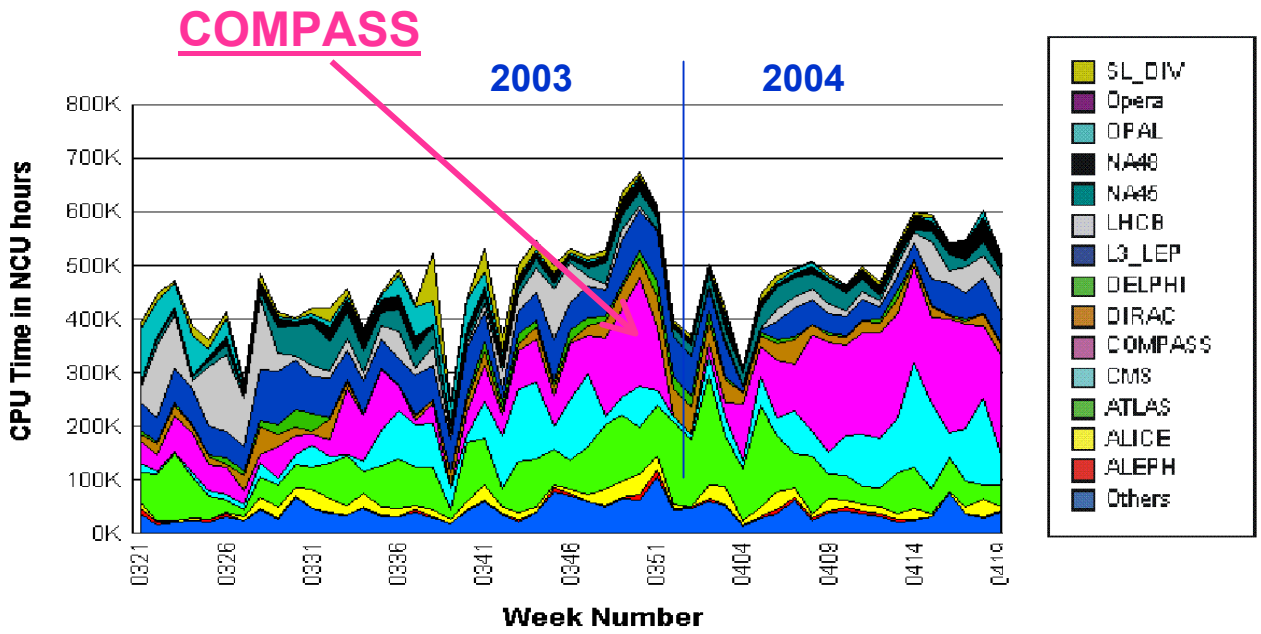
2002

DATA PROCESSING at CERN



500 TB of raw data
→ 500 000 jobs batch
(1 GByte ~ 8 h)

Processing in parallel as much as possible

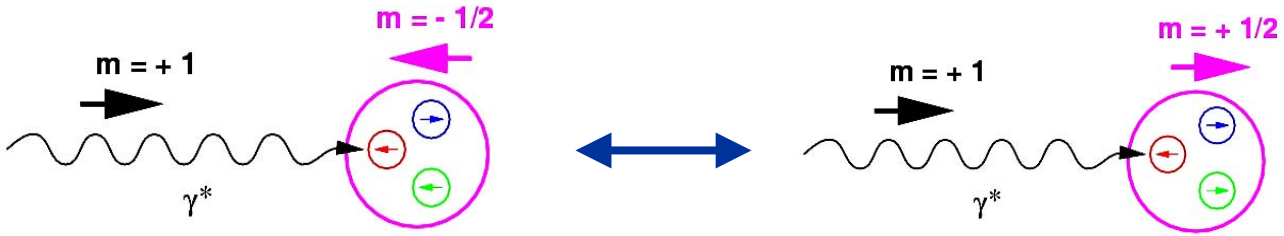


FIRST PHYSICS RESULTS

- A_1^D
- A_{LL} from *high* p_T
- Transversity

DOUBLE SPIN ASYMMETRY A_1^d

virtual photon-deuteron aymmetry



$$\sigma_{1/2} \approx \sum_a e_a^2 \cdot q_a^+ \qquad \sigma_{3/2} \approx \sum_a e_a^2 \cdot q_a^-$$

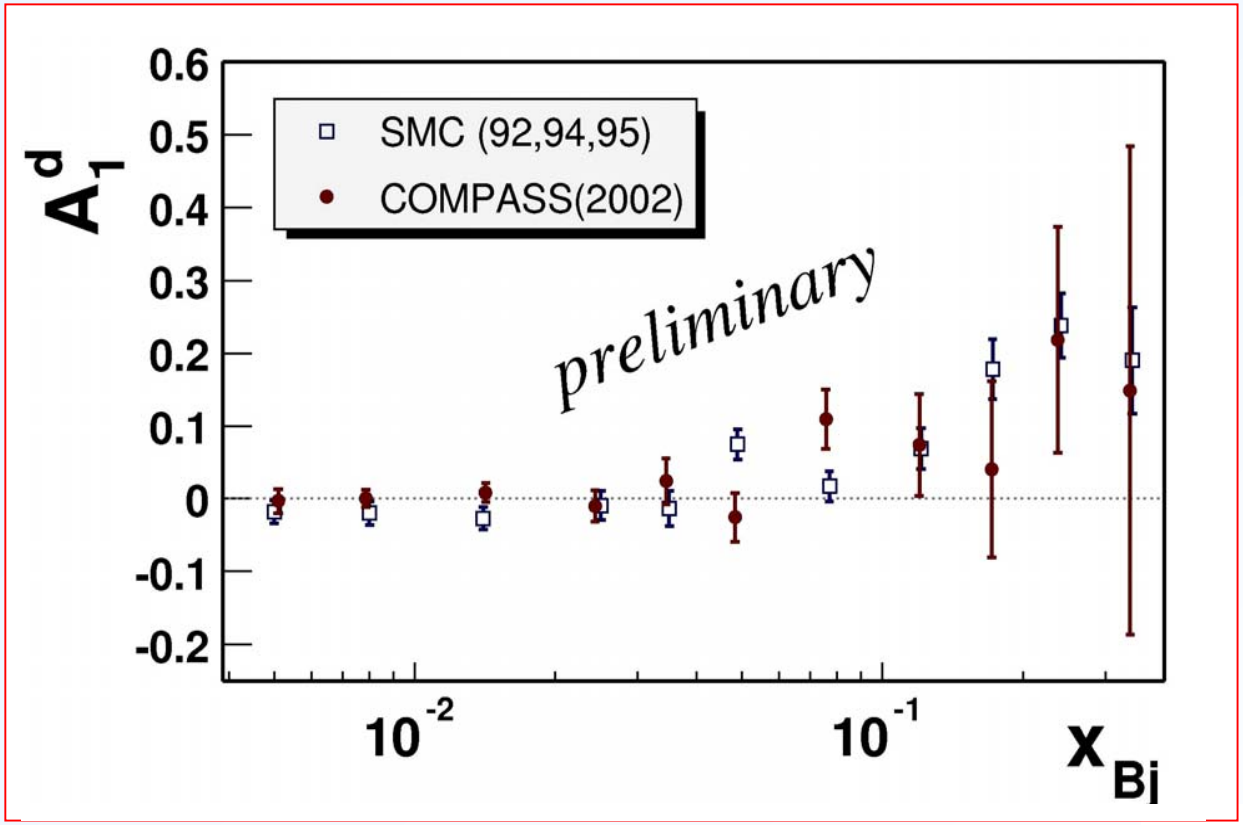
$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} - \sigma_{3/2}} \approx \frac{\sum_a e_a^2 \cdot \left(q_a^+ - q_a^-\right)}{\sum_a e_a^2 \cdot \left(q_a^+ + q_a^-\right)}$$

$$g_1 = \frac{1}{2} \cdot \sum_a e_a^2 \cdot \left(q_a^+ - q_a^-\right)$$

$$F_1 = \frac{1}{2} \cdot \sum_a e_a^2 \cdot \left(q_a^+ + q_a^-\right)$$

$$A_1 \approx \frac{g_1}{F_1}$$

DOUBLE SPIN ASYMMETRY A_1^d



COMPASS:

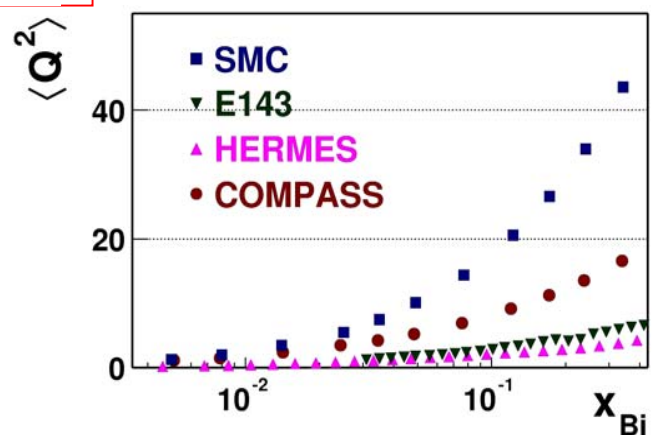
2002 data only

6.5 Million DIS events

$Q^2 > 1$ (GeV/c)^2

$0.1 < y < 0.9$

expect x4 statistics by end of 2004

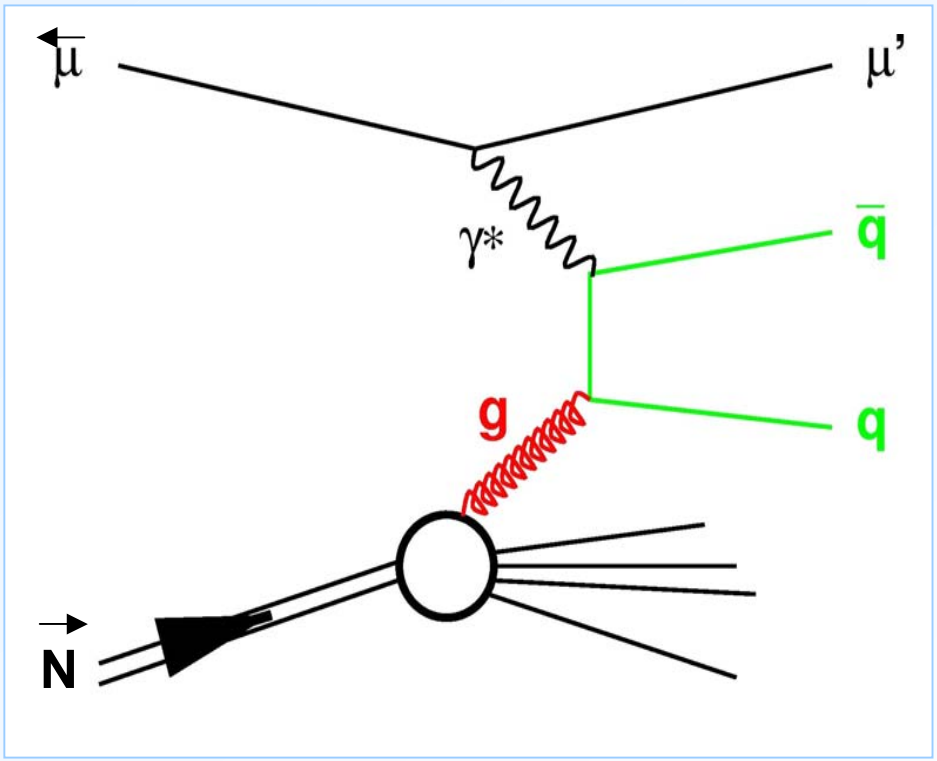


Data displayed at experimental $\langle Q^2 \rangle$ of every x_{Bj} bin

F. Bradamante, May 28

ΔG/G at COMPASS

Photon Gluon Fusion



q = c cross section difference in charmed meson production

→ *theory well understood*

→ *experiment challenging*

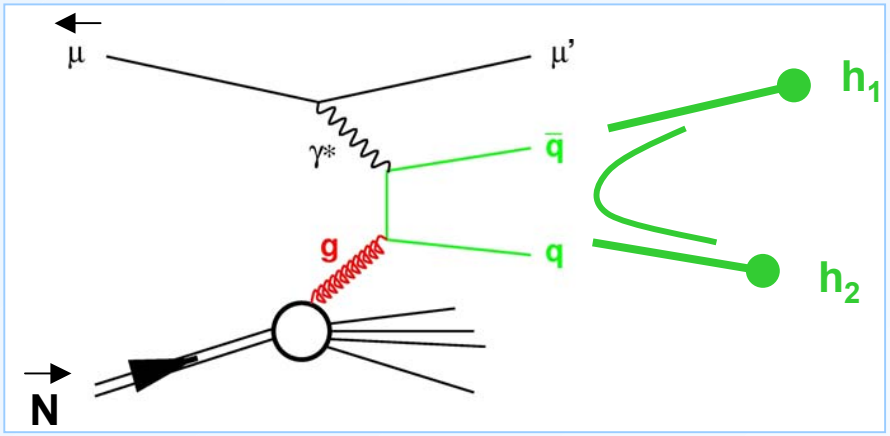
q = u,d,s cross section difference in 2+1 jet production in COMPASS: events with 2 hadrons with high p_T

→ *experiment easy*

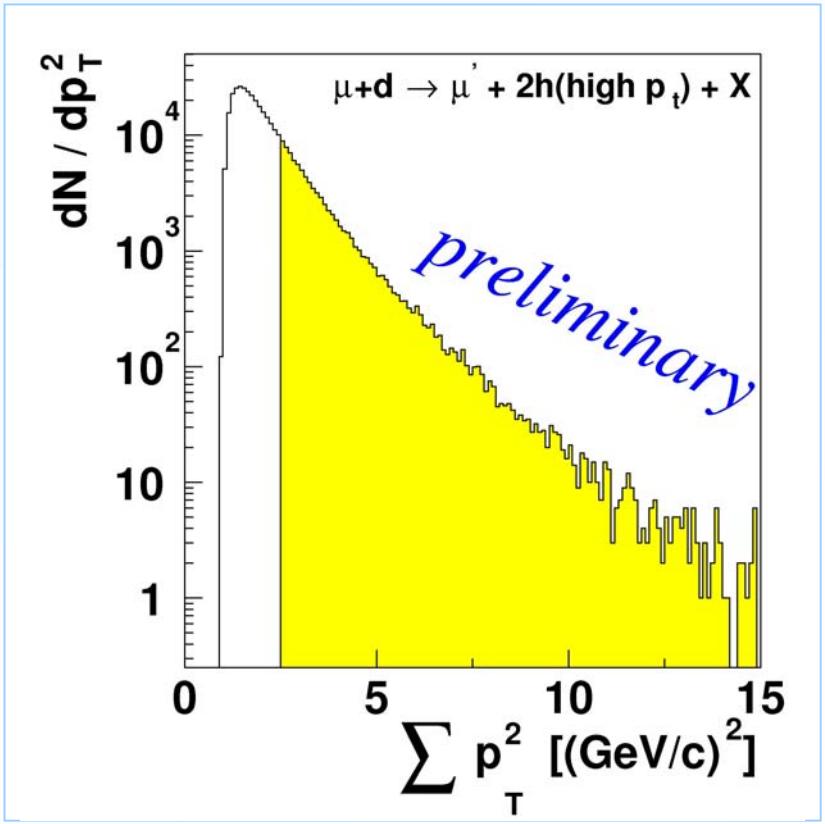
→ *theory difficult*

ΔG/G: pairs of high p_T hadrons

Photon Gluon Fusion



- Current fragmentation
  - $x_F > 0.1$
  - $z > 0.1$
- 2 high p_T hadrons
  - $p_T > 0.7$ GeV/c
  - $p_{T1}^2 + p_{T2}^2 > 2.5$ (GeV/c)^2
  - $m(h_1h_2) > 1.5$ GeV/c^2



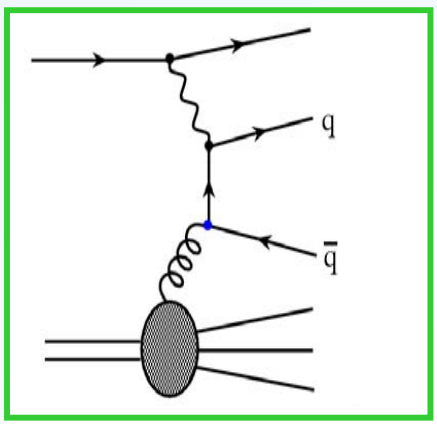
ΔG/G: pairs of high p_T hadrons

$$A^{\gamma^* d} = \frac{1}{2P_T\, f\, D\, P_B}\left[\frac{N_1^{\Leftarrow} - N_2^{\Leftarrow}}{N_1^{\Leftarrow} + N_2^{\Leftarrow}} + \frac{N_2^{\Leftarrow} - N_1^{\Leftarrow}}{N_2^{\Leftarrow} + N_1^{\Leftarrow}}\right]$$

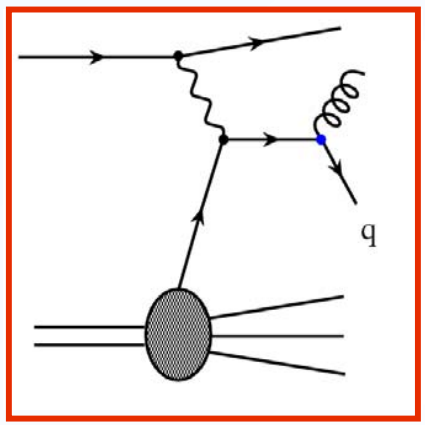
$\hat{a}_{LL}^{PGF} \approx -1$ and $\hat{a}_{LL}^{Com} \approx 0.5$

fractions of cross section determined by Monte Carlo

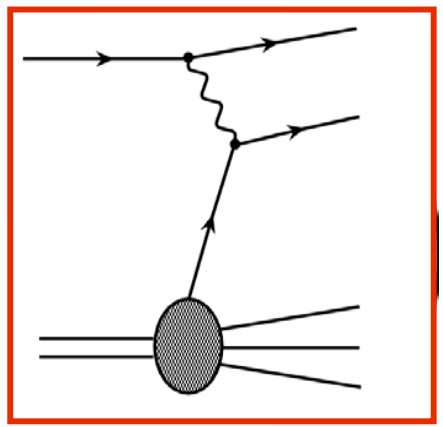
$$A^{\gamma^* d} = \frac{A_{LL}^{\mu N \to hh}}{D} \approx \left\langle \frac{\hat{a}_{LL}^{PGF}}{D} \right\rangle \left\langle \frac{\Delta G}{G} \right\rangle \frac{\sigma^{PGF}}{\sigma^{tot}} + \left\langle \frac{\hat{a}_{LL}^{Com}}{D} \right\rangle \left\langle \frac{\Delta q}{q} \right\rangle \frac{\sigma^{Com}}{\sigma^{tot}} + LO\,DIS$$



Photon Gluon Fusion



QCD-Compton



Leading Order

$\Delta G/G$: pairs of high p_T hadrons

Asymmetry in production of hadron pairs with high p_T: preliminary result from 2002 data

$$A^{\gamma^* d} = -0.065 \pm 0.036_{stat.} \pm 0.010_{syst.}$$

up to now systematic error contains only studies on false asymmetries due to target or spectrometer effects

assuming R_{PGF} ~ 1/4 **$\sigma(\Delta G/G) \sim 0.17$**

… and $\Delta G/G > 0$

Improvements:

- **2003 and expected 2004 data will give a factor of 4 more data**
- **better reconstruction algorithm, ... $\sigma(\Delta G/G) \rightarrow 0.05$**

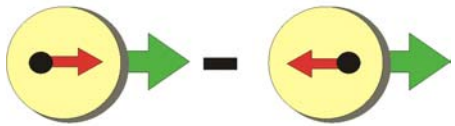
TRANSVERSE SPIN PHYSICS

3 structure functions are necessary to describe the spin structure of the nucleon at LO:

$q(x)$ $f_1(x)$

momentum distribution

$\Delta q(x)$ $g_1(x)$



helicity distribution

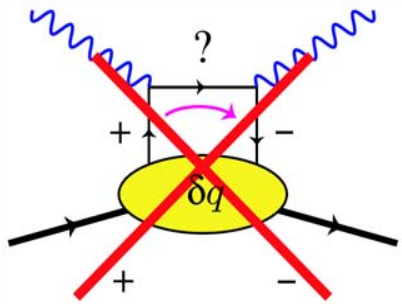
$\Delta_T q(x)$ $h_1(x)$

transversity distribution

all of equal importance!

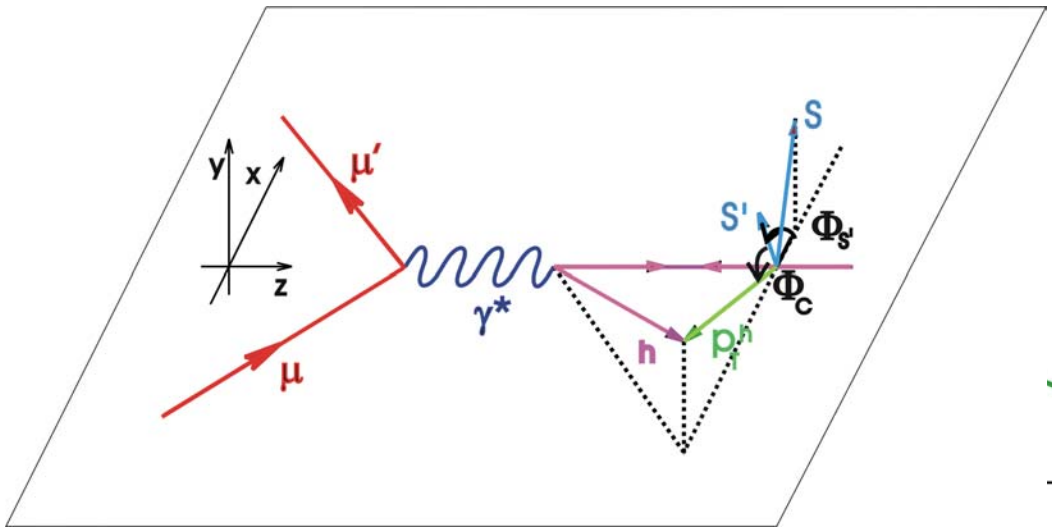
$h_1(x)$ decouples from leading twist DIS because helicity of quark must flip

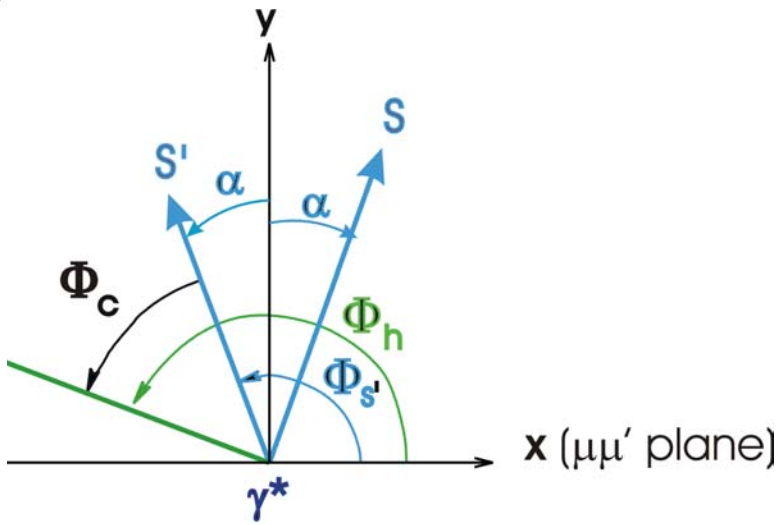
NO MIXTURE WITH GLUON



COLLINS ASIMMETRY

$$\Phi_C = \Phi_h - \Phi_{s'}$$



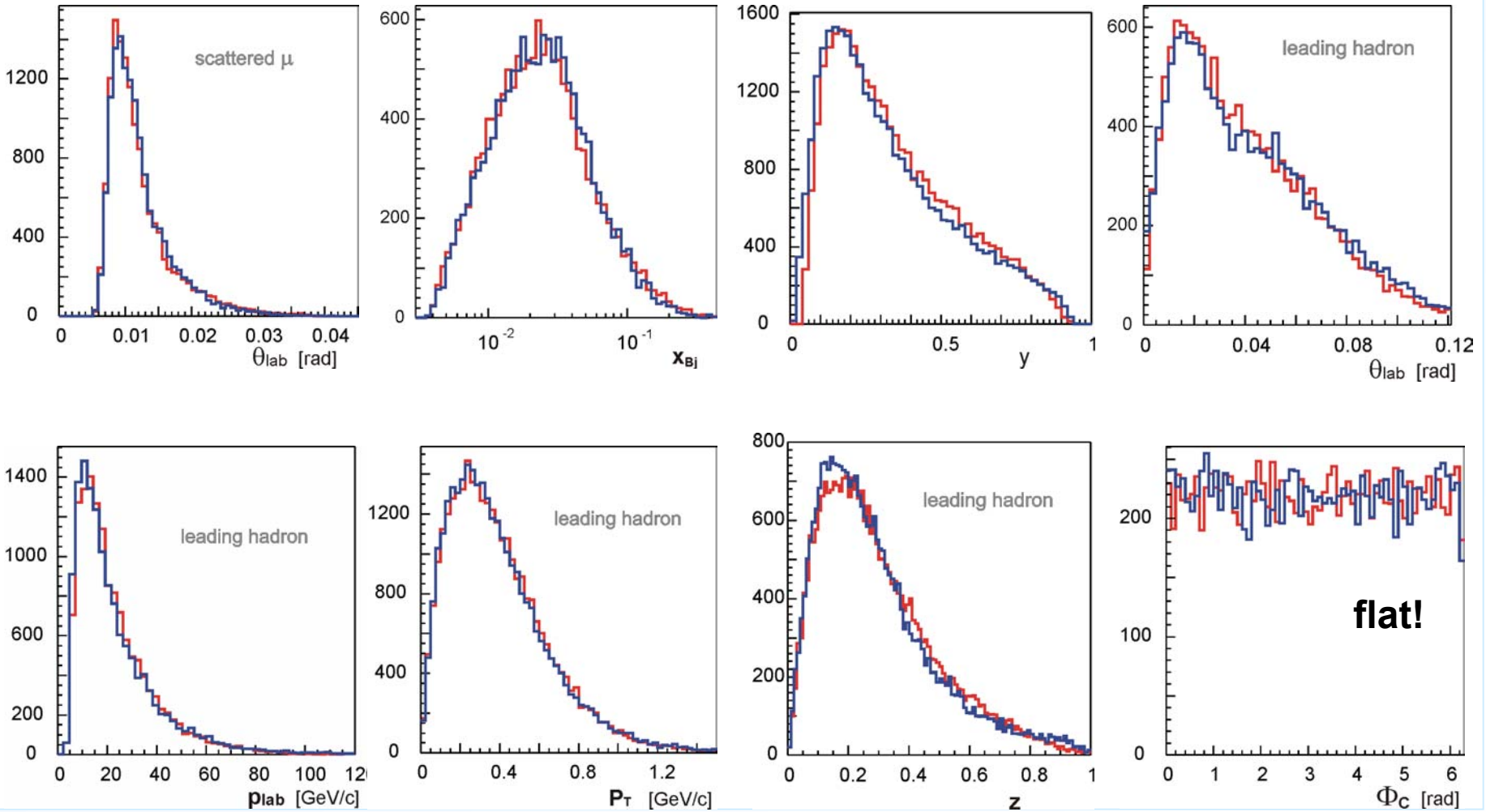


$$N_h^{\pm}(\Phi_C) = N_h^0 \cdot \left\{ 1 \pm A_1^h \cdot \sin\Phi_C \right\}$$

$$A_{Coll} = \frac{1}{f \cdot P_T \cdot D_{nn}} \cdot A_1^h = \frac{\sum_a e_a^2 \cdot \Delta_T q_a \cdot \Delta D_a^h}{\sum_a e_a^2 \cdot q_a \cdot D_a^h}$$

COLLINS ASYMMETRY

MC vs DATA



COLLINS ASYMMETRY

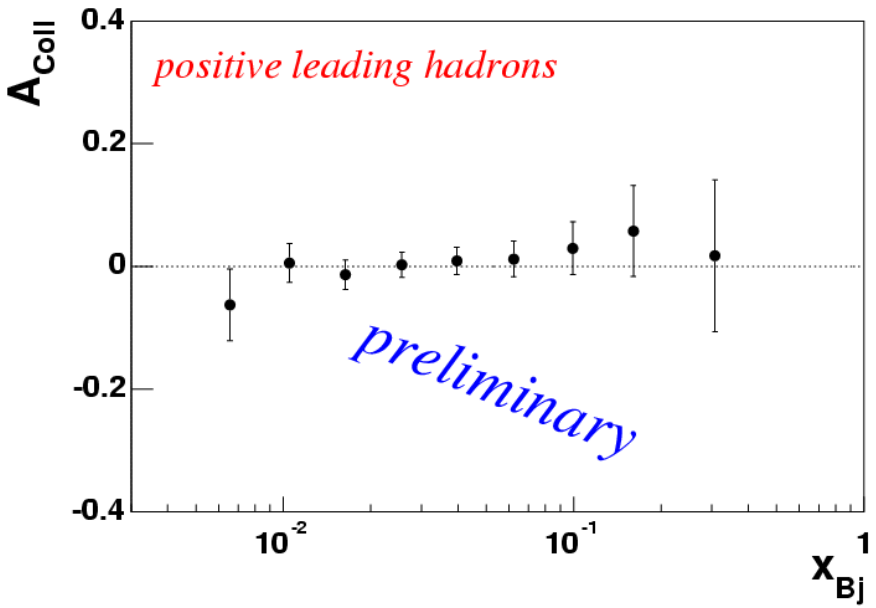
RESULTS

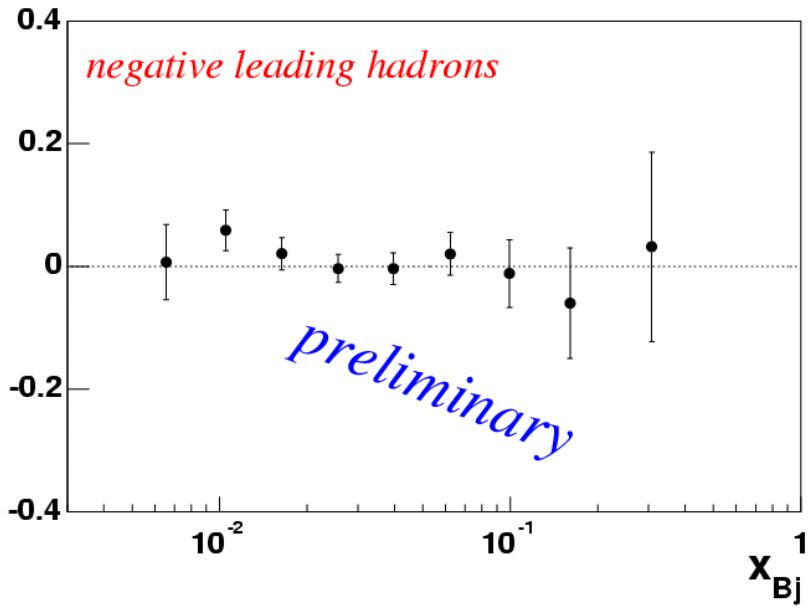
A_{coll} depends on p_{hT}, z_h, x_{Bj}

with more statistics, the full analysis is foreseen

from 2002 data:

A_{coll} vs x_{Bj}



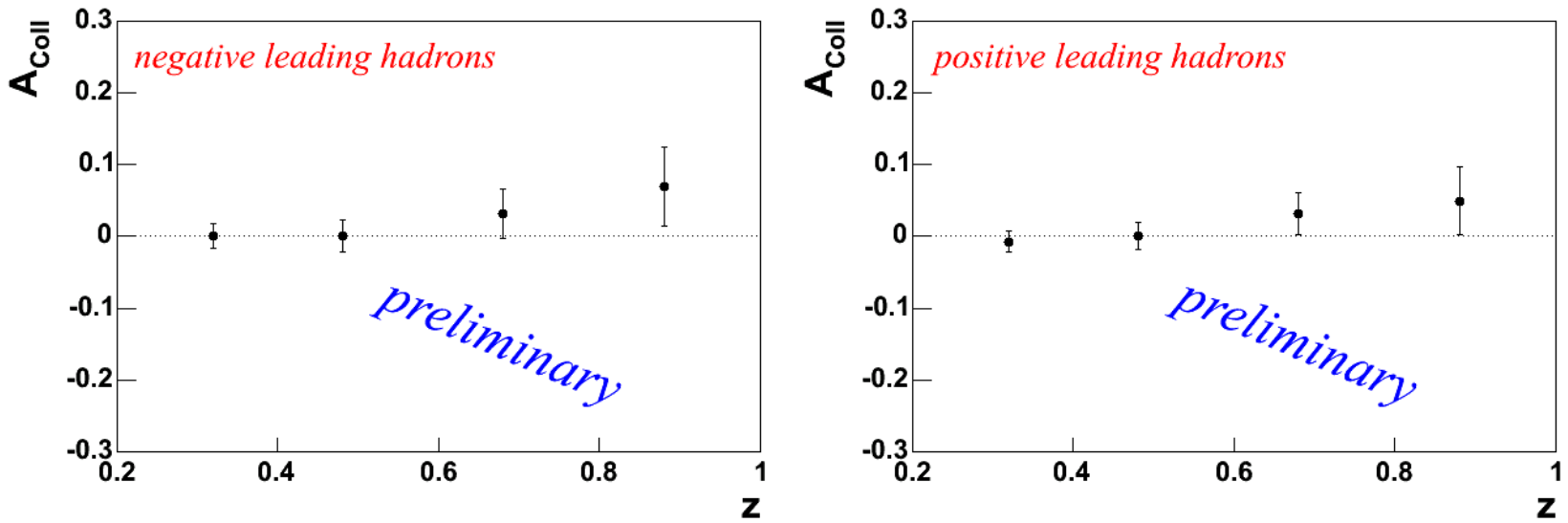


COLLINS ASYMMETRY

RESULTS

from 2002 data:

A_{Coll} vs z_h



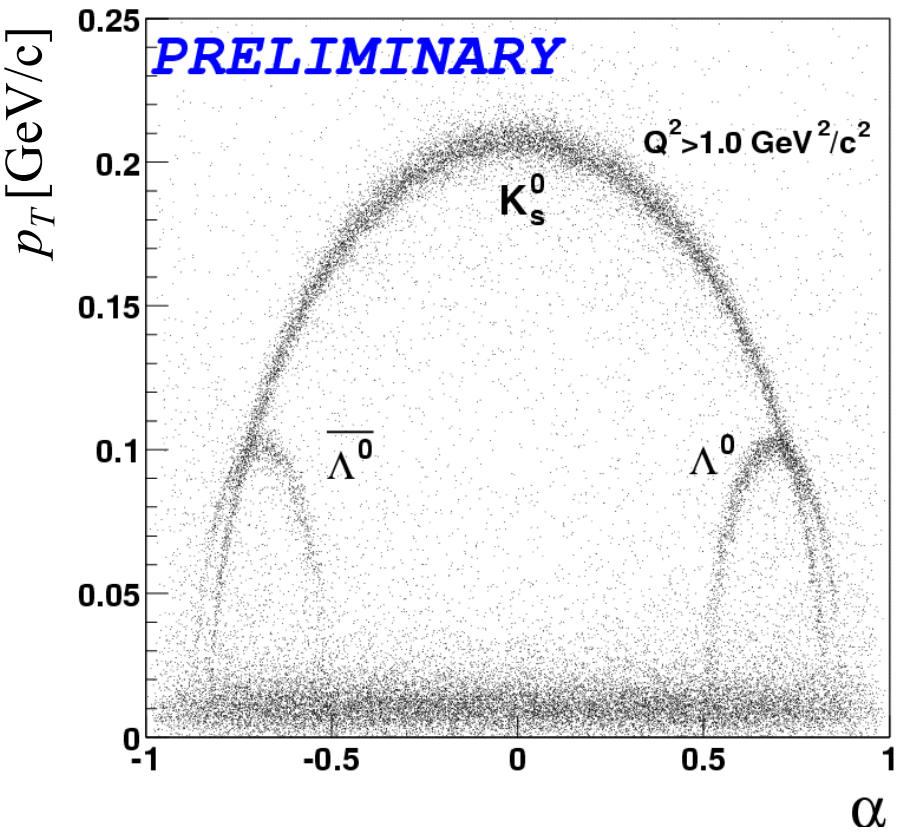
all the tests we made are consistent with the fact that

systematic effects, if present, are smaller than statistical errors

ONGOING ANALYSIS

- Λ and $\overline{\Lambda}$ hyperon production
- Vector meson production ρ, ϕ and J/ψ
- Flavour decomposition of polarized PDF
- ΔG/G from open charm

Λ PRODUCTION



Armenteros-Podolanski

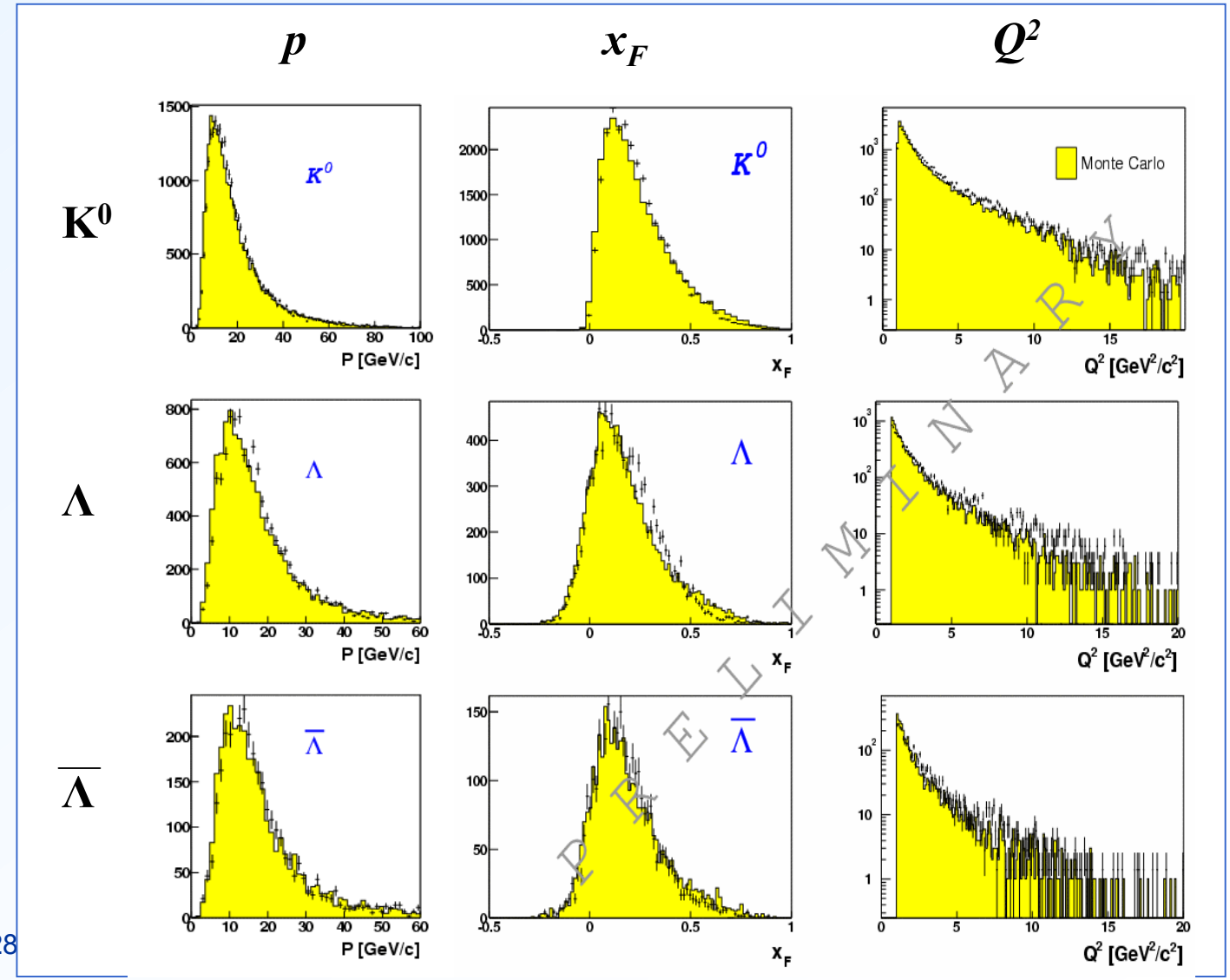
$$\alpha = \frac{P_L^+ - P_L^-}{P_L^+ + P_L^-}$$

Λ PRODUCTION

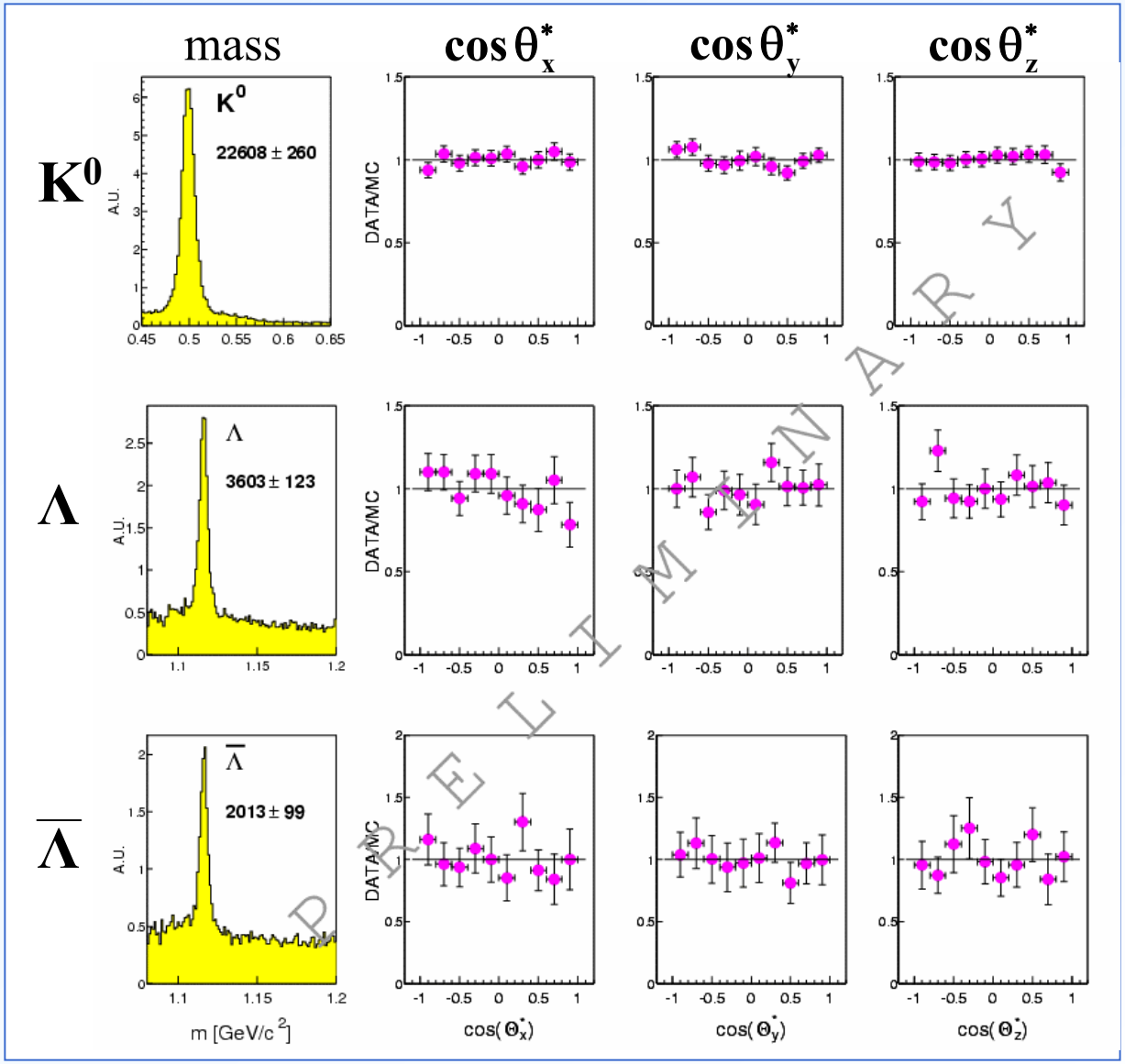
DATA vs MONTECARLO

Data

Monte Carlo



Λ POLARIZATION ?



1/6 of 2002 statistics

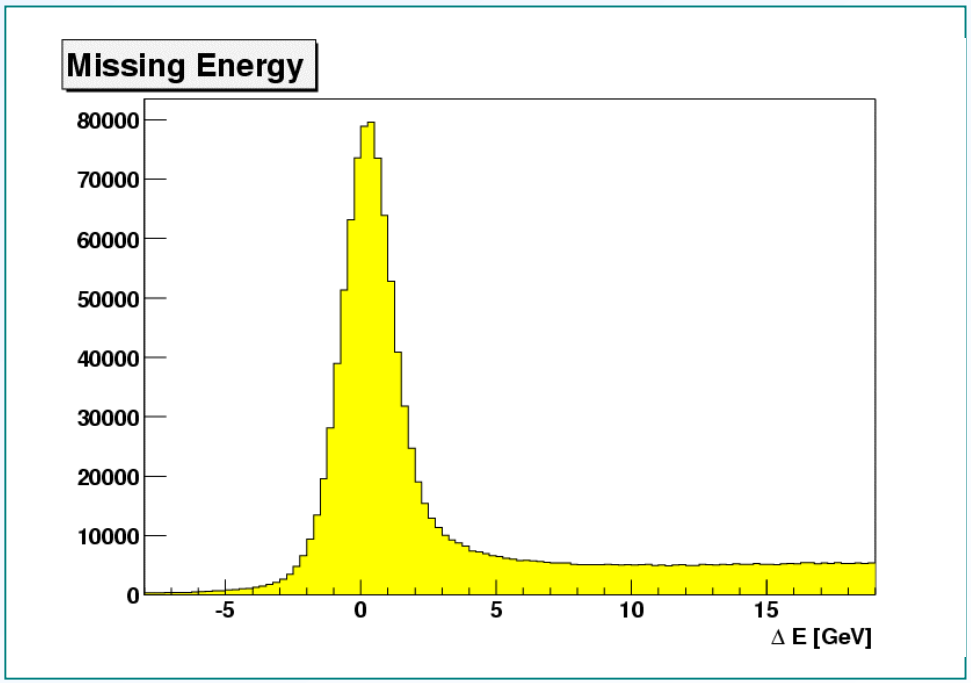
$$Q^2 > 1\,\mathrm{GeV}^2$$

$$0.2 < y < 0.9$$

good potential for polarization measurement

EXCLUSIVE ρ and ϕ PRODUCTION

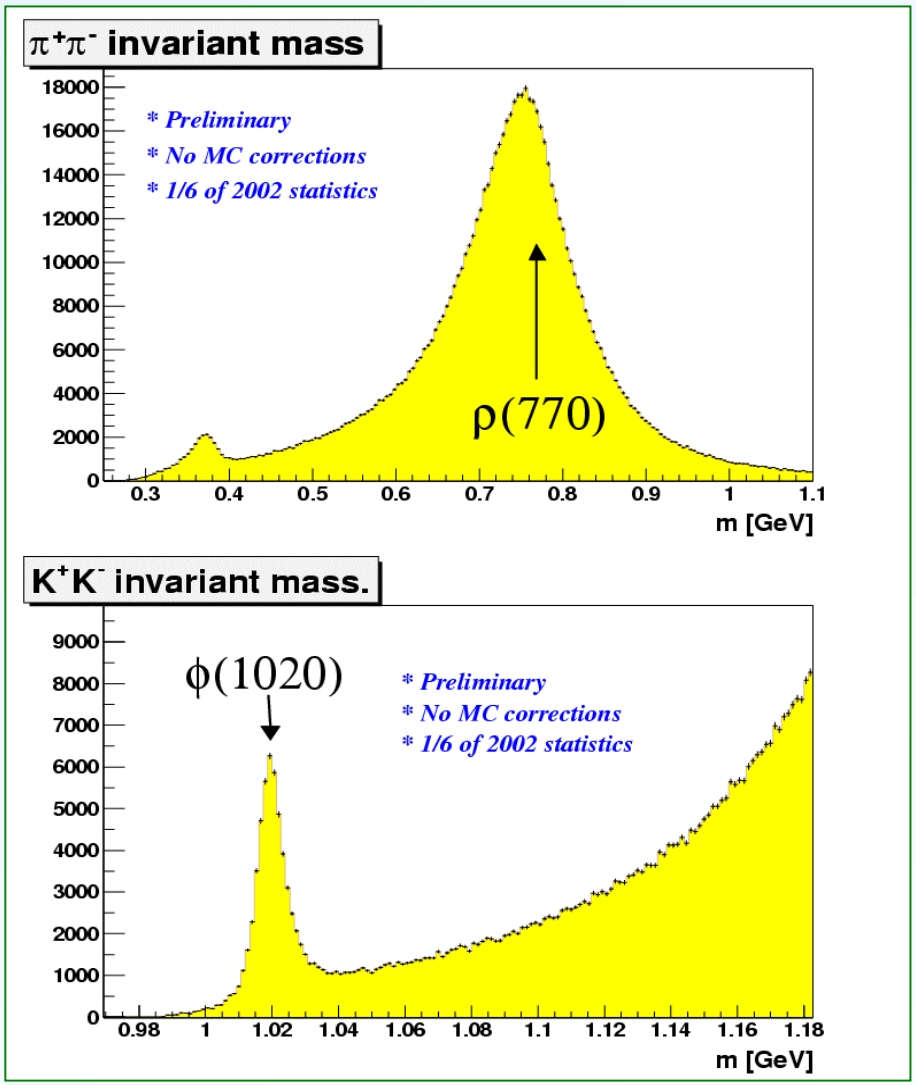
meson	mass cut	statistics (1/6 of 2002)
ρ^0	$0.5 < m_{\pi\pi} < 1\ \mathrm{GeV}$	$1.3 \cdot 10^6$
ϕ	$\lvert m_{KK} - m_{\phi} \rvert < 9\ \mathrm{MeV}$	$42 \cdot 10^3$



- $|t'| < 0.5\ \mathrm{GeV}^2$
- $7.5 < W < 16\ \mathrm{GeV}$
- $Q^2 > 10^{-3}\mathrm{GeV}^2$

EXCLUSIVE ρ and ϕ PRODUCTION

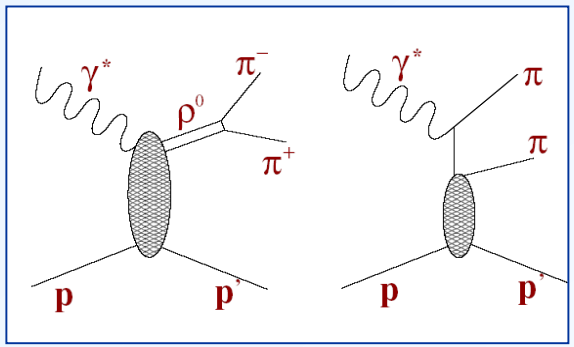
INVARIANT MASSES



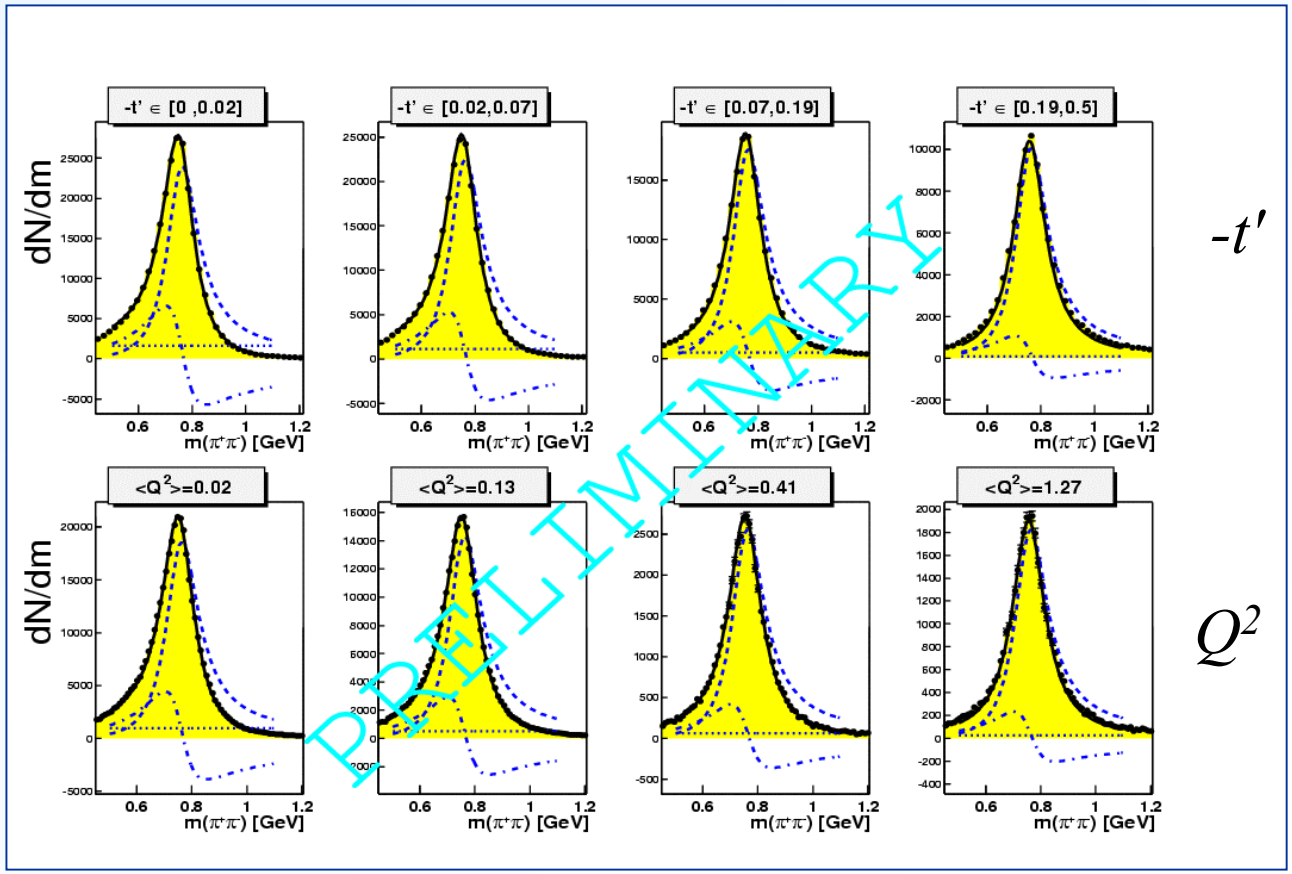
- 16 % of total 2002 statistics
- no MC corrections yet

EXCLUSIVE ρ and ϕ PRODUCTION

INTERFERENCE of ρ^0 and $\pi\pi$

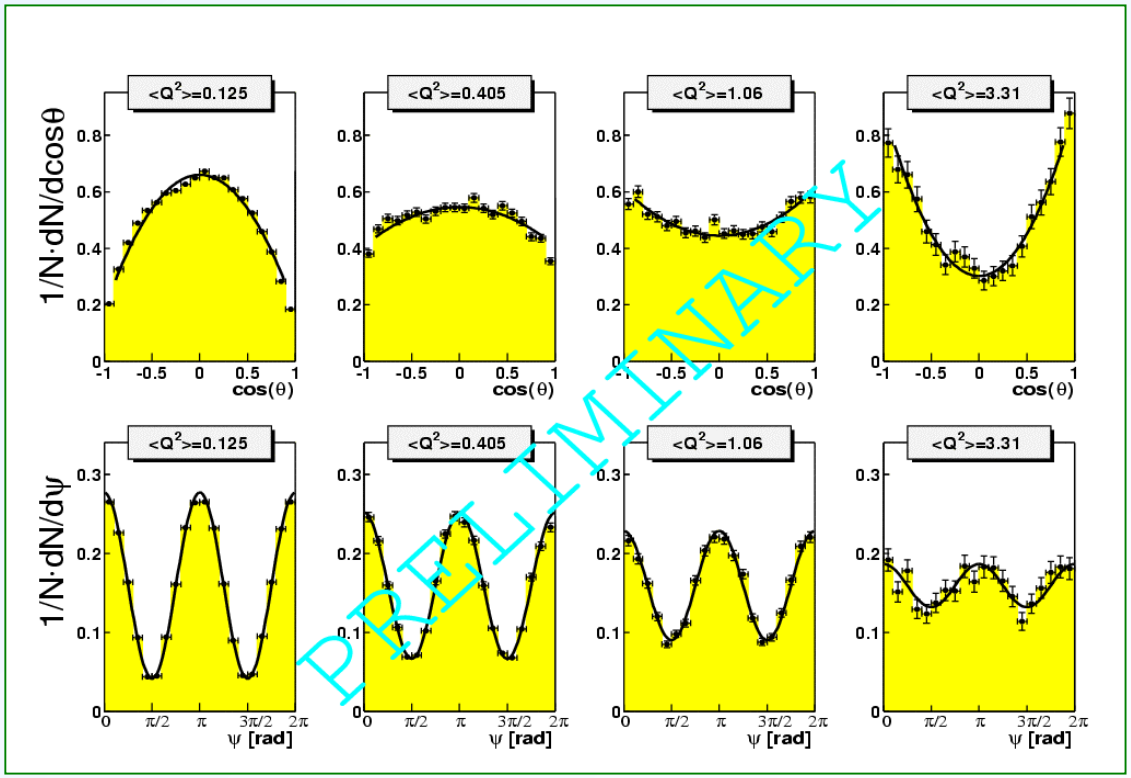


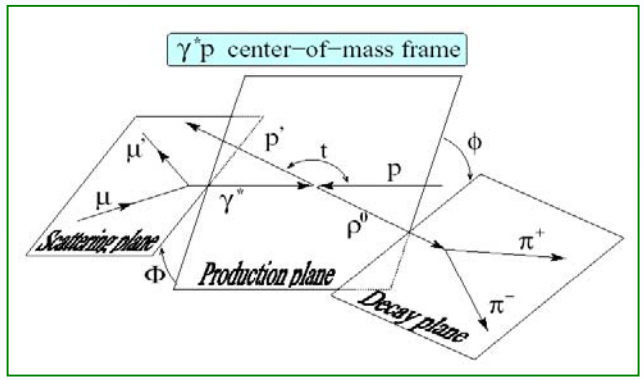
- **Söding parametrization**
- **No accept. corr.**



EXCLUSIVE ρ and ϕ PRODUCTION

ANGULAR DISTRIBUTIONS



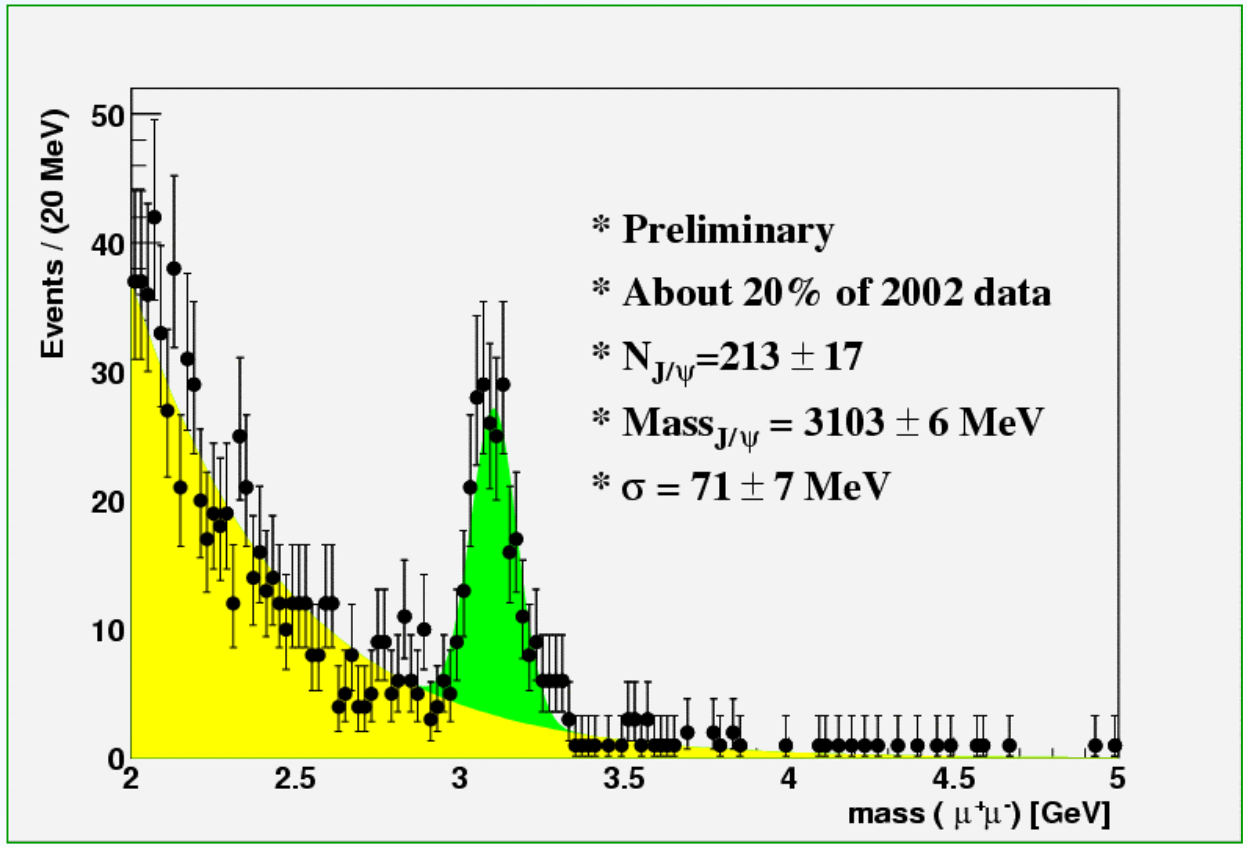


$p_T > 0.15$ GeV $\qquad Q^2 > 0.05$ GeV^2

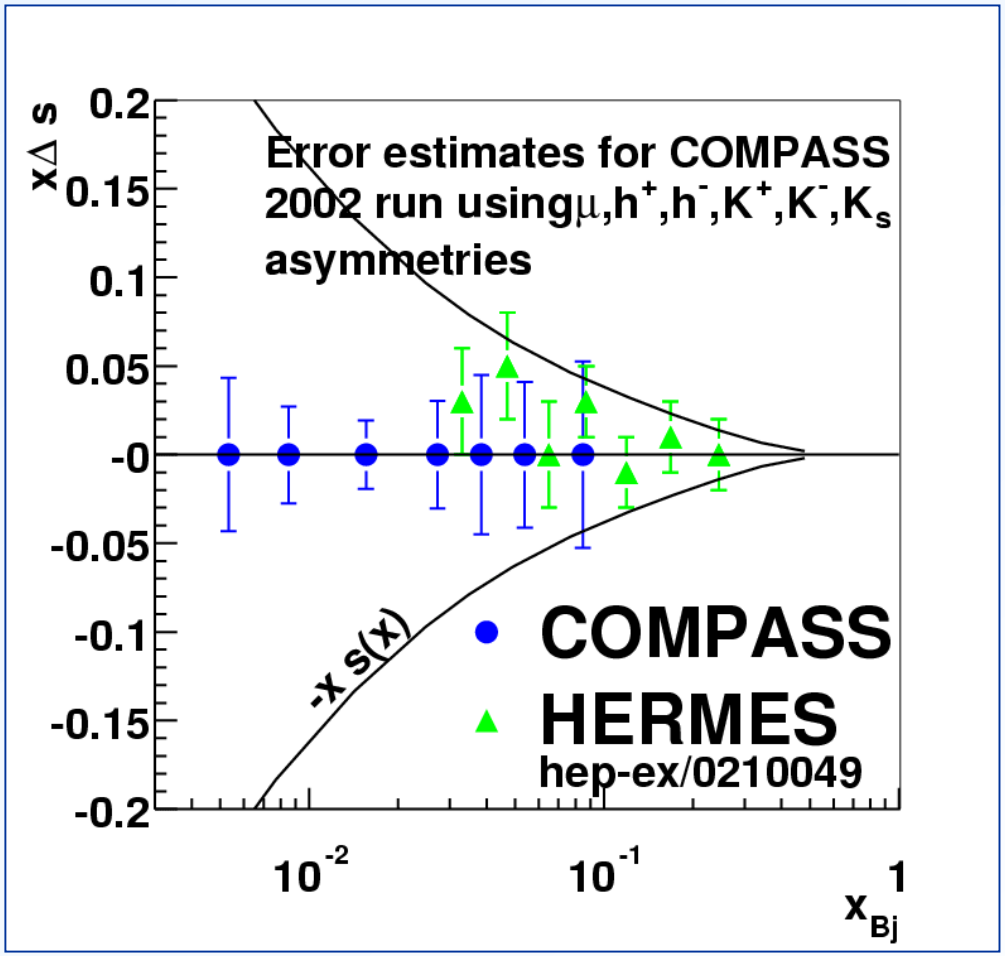
J/ψ PRODUCTION

$J/\psi \rightarrow \mu^+ \mu^-$

- first look
- mainly elastic



FLAVOUR SEPARATION Δq



Looks very promising in particular for Δs !

Can the first moment of Δs be positive?

Low-*x* data essential!

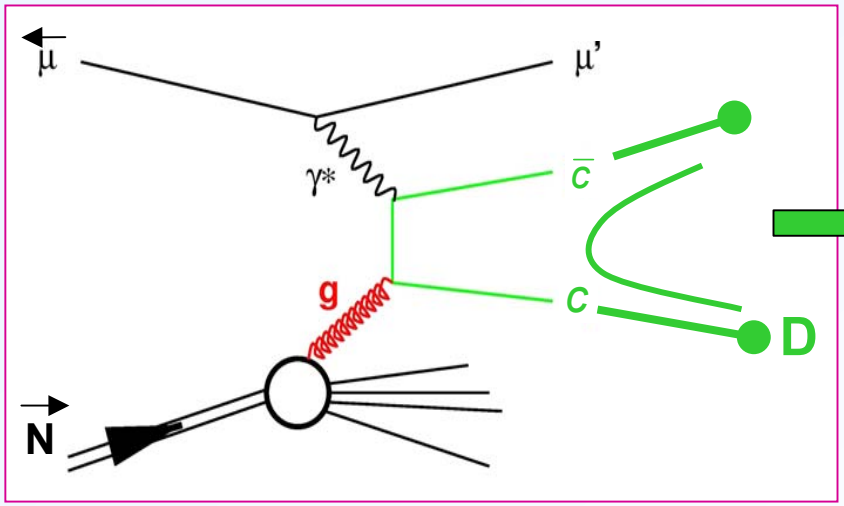
ΔG/G: OPEN CHARM

$$A_{\gamma N}^{c\bar{c}} = \frac{\Delta\sigma^{\gamma N \to c\bar{c}X}}{\sigma^{\gamma N \to c\bar{c}X}} = \frac{\int d\hat{s}\, \Delta\sigma^{PGF}(\hat{s})\, \Delta G(x_G, \hat{s})}{\int d\hat{s}\, \sigma^{PGF}(\hat{s})\, G(x_G, \hat{s})} \approx \langle a_{LL} \rangle \left\langle \frac{\Delta G}{G} \right\rangle$$

$$\hat{s} = M_{c\bar{c}}^2$$

$\Delta\sigma^{PGF}$ at NLO: Bojak, Stratmann NPB 540 (1999) 345; Contogouris *et al.*

Photon-Gluon Fusion



$$D^0 \to K^- \pi^+ \quad \text{(BR 4 \%)}$$

$$D^{*+} \to D^0 \pi^+ \to \left(K^- \pi^+\right) \pi^+$$

$$A_{raw} = \frac{N_{c\bar{c}}^{\Rightarrow,\Leftarrow} - N_{c\bar{c}}^{\Rightarrow,\Leftarrow}}{N_{c\bar{c}}^{\Rightarrow,\Leftarrow} + N_{c\bar{c}}^{\Rightarrow,\Leftarrow}} = P_\mu P_T f D A_{\gamma N}^{c\bar{c}}$$

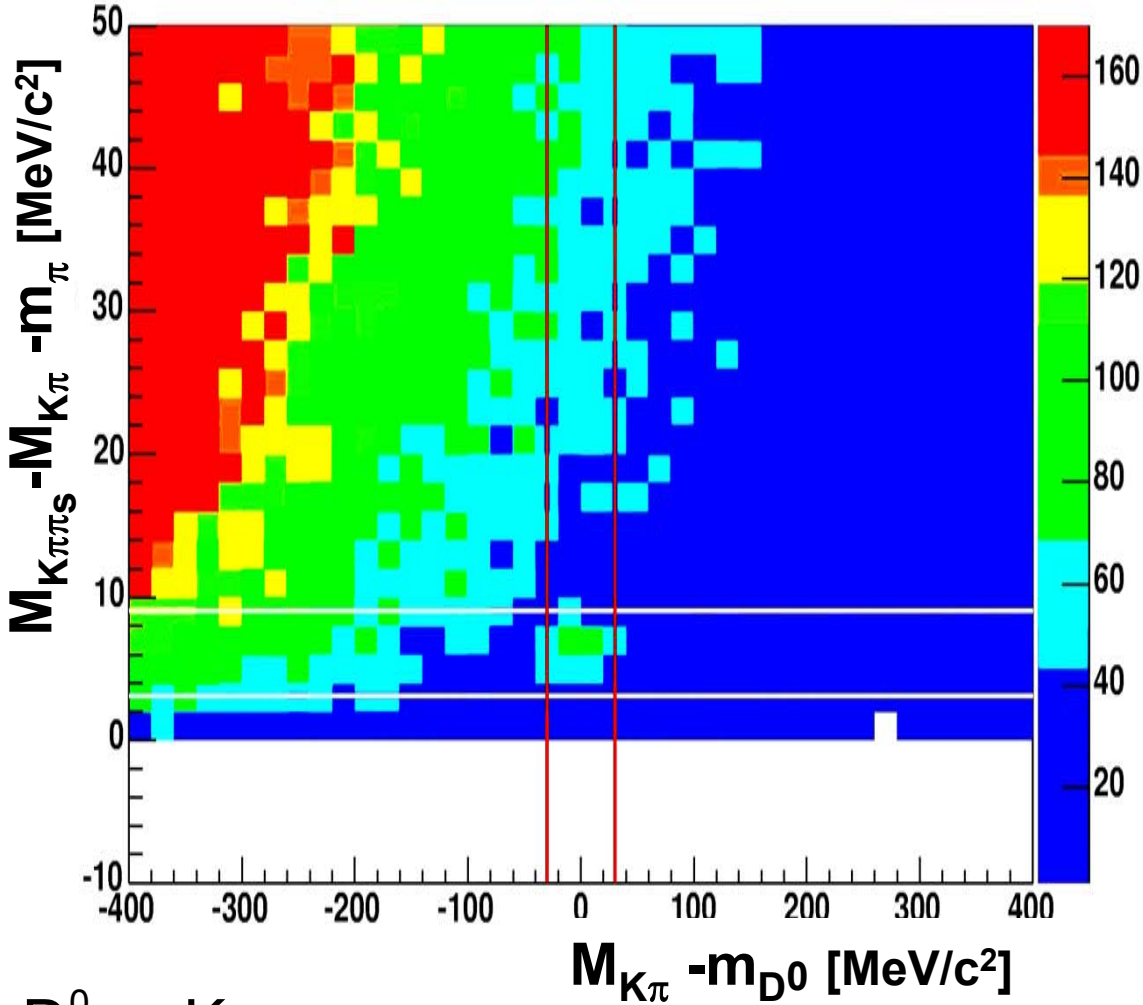
$P_\mu \approx -0.76$ $\quad f \approx 0.4$

$P_T \approx 0.5$ $\quad D(y)$

D* tagging: $D^* \to D^0 \pi$

$D^* \to (K\pi)\pi$

$D^* \to (K\pi)\pi$



$D^0 \to K\pi$

Cuts:

$z_D > 0.2$

$|\cos \theta^*| < 0.85$

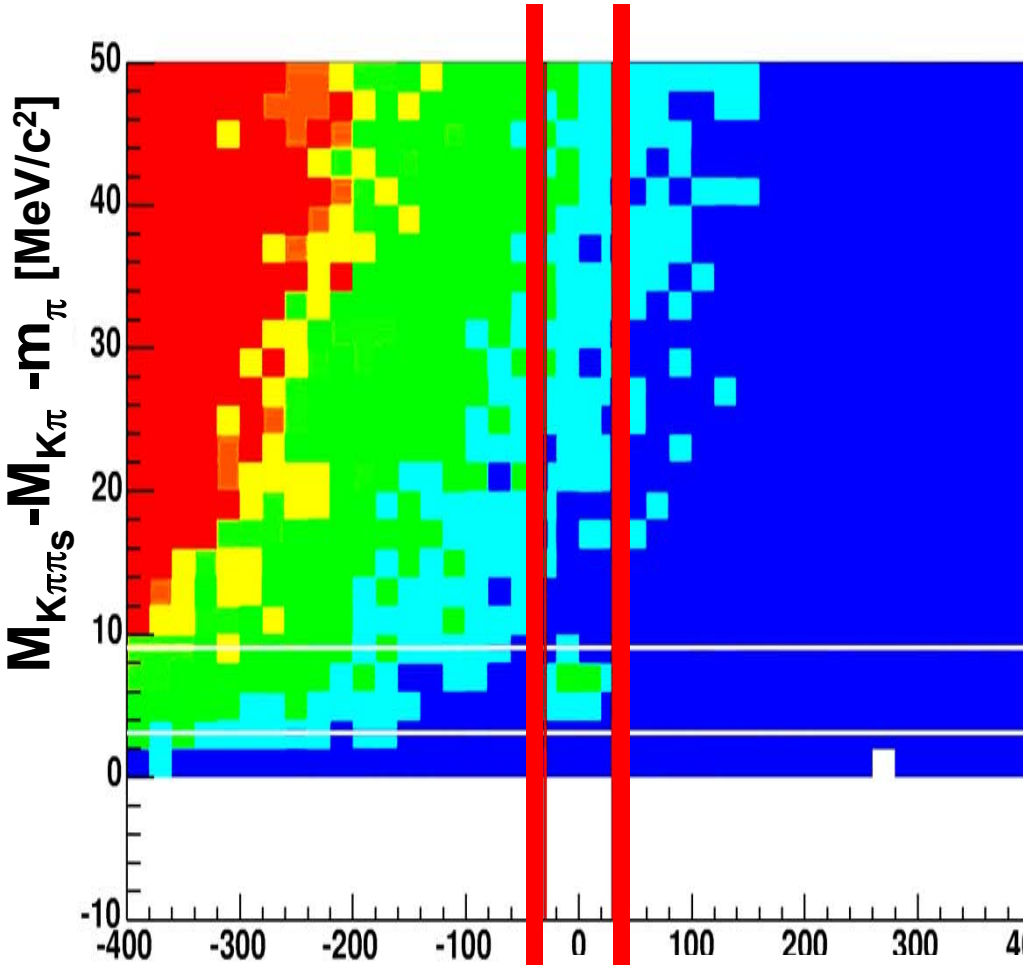
(Background)

$10 < p_K < 35$ GeV/c

(RICH PID)

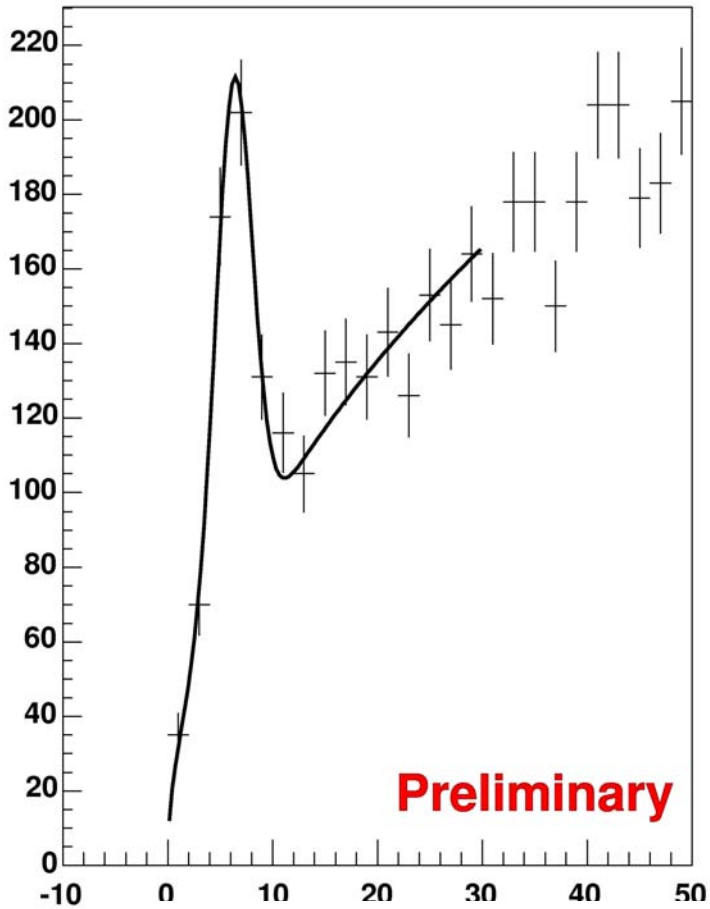
D* tagging: $D^* \to D^0 \pi$

$D^* \to (K\pi)\pi$



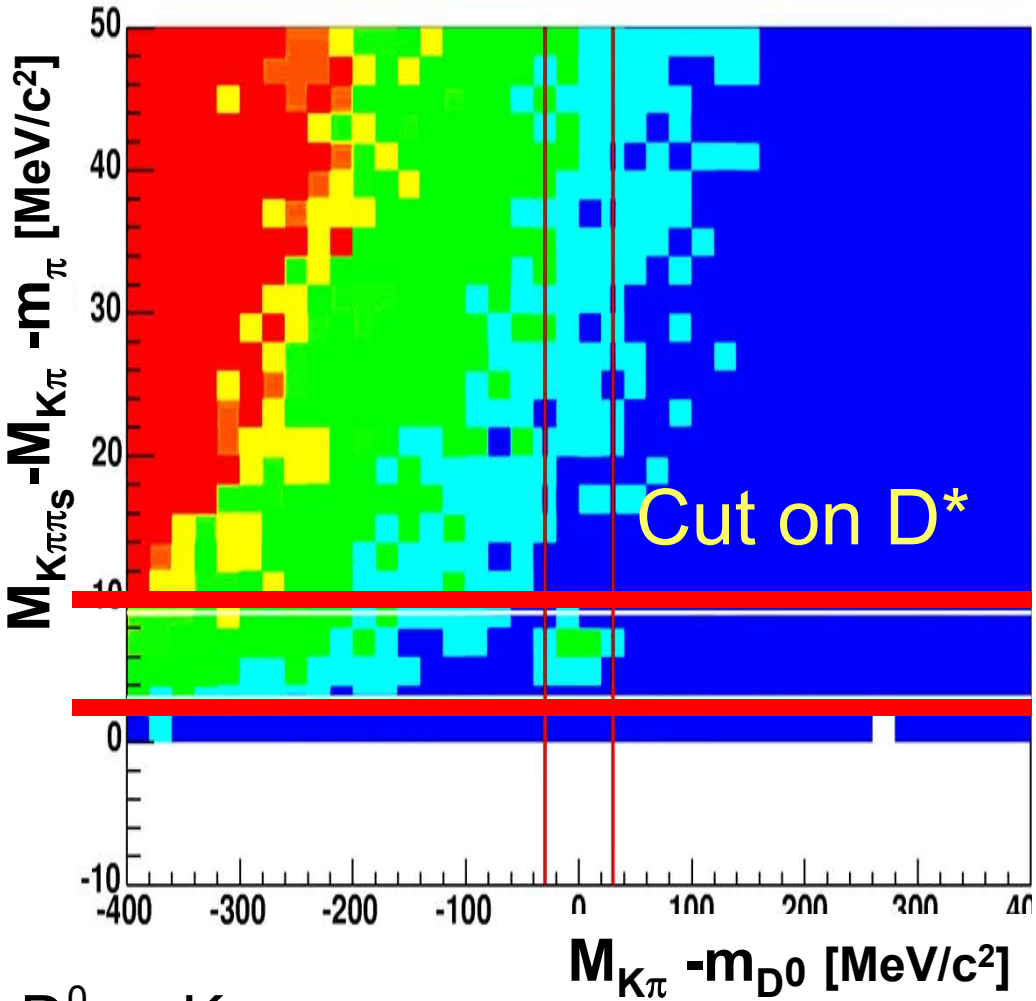
$D^0 \to K\pi$

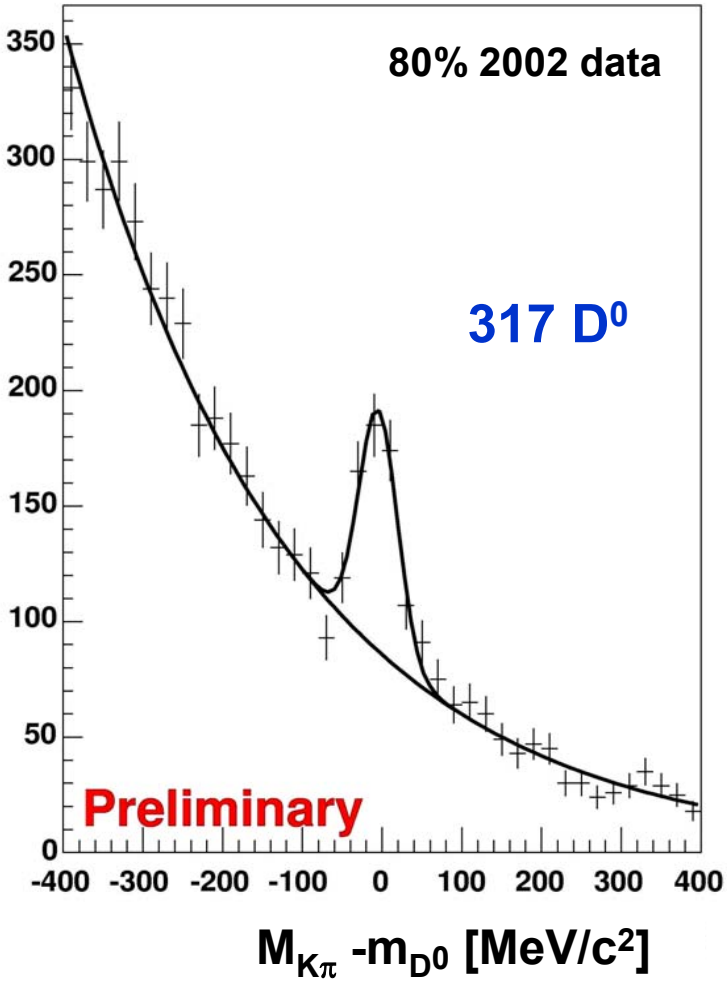
$D^* \to (K\pi)\pi$



D* tagging: $D^* \to D^0 \pi$

$D^* \to (K\pi)\pi$ $\quad$ $D^0 \to K\pi$





$D^0 \to K\pi$

PROJECTIONS FOR $\sigma(\Delta G/G)$

With

- ***improved FOM and***
- ***assuming ~ 80 scheduled days (only L data) in 2004***

we expect for all the deuteron data (2002, 2003, 2004)

$\sigma(\Delta G/G) = 0.24$ **from open charm**

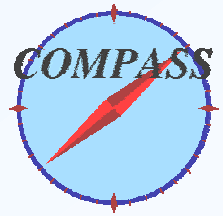
$\sigma(\Delta G/G) = 0.05$ **from high** p_T ***all Q2***

$\sigma(\Delta G/G) = 0.16$ **from high** p_T $Q^2>1$

resolved γ

σ_{syst} ?

SUMMARY AND OUTLOOK



- CERN is again contributing to the *NUCLEON SPIN PUZZLE*
- a technically challenging new experiment is IN OPERATION SINCE 2002

  "LHC" technologies *detectors*
  read-out
  data handling

- a privileged situation at CERN
- FIRST PHYSICS RESULTS have been produced
  MANY MORE IN THE PIPE-LINE
- COMPASS is foreseen to run up to the end of the present mid-term plan of CERN (2010)

BIG DISCOVERY POTENTIAL

thank you

thank you

and

see you all at

spin2004

F. Bradamante, May 28