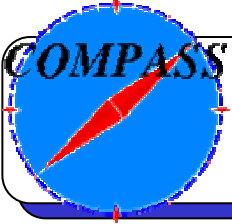


# COMPASS @ CERN

## Status, prospect

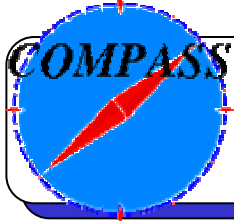
Alain Magnon CEA/Saclay

*On behalf of COMPASS Collaboration*



# Content

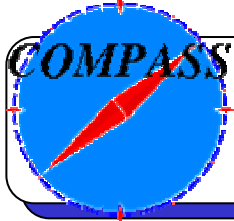
- COMPASS, physics programme
- Spectrometer highlights
- Preliminary physics results (2002)
- Prospects beyond 2005



# COMPASS Collaboration

Bielefeld, Bochum, Bonn (ISKP, PI), Burdwan and Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Moscow (INR, LPI, MSU), Munich (LMU, TU), Nagoya, Prague, Protvino, Saclay, Tel Aviv, Torino (Univ., INFN), Trieste (Univ., INFN), Warsaw (SINS, TU)

More than 250 physicists from 28 Institutes



# Physics programme

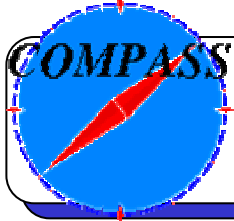
## Hadron structure and spectroscopy

### Muon beam programme

- Quarks and gluon polarisation in polarised (longitudinal) nucleons
- Transverse spin distribution
- Diffractive VM-production
- DVCS  $\rightarrow$  GPDs (not approved yet)

### Hadron beam programme

- Polarisability of pions and kaons (Primakoff reaction)
- Exotics  $q$ -states, glue balls
- Semi-leptonic decays of charmed hadrons
- Double charmed hadrons



# Quark & gluon spin

$$\text{Nucleon spin: } \frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + \langle L_z \rangle$$

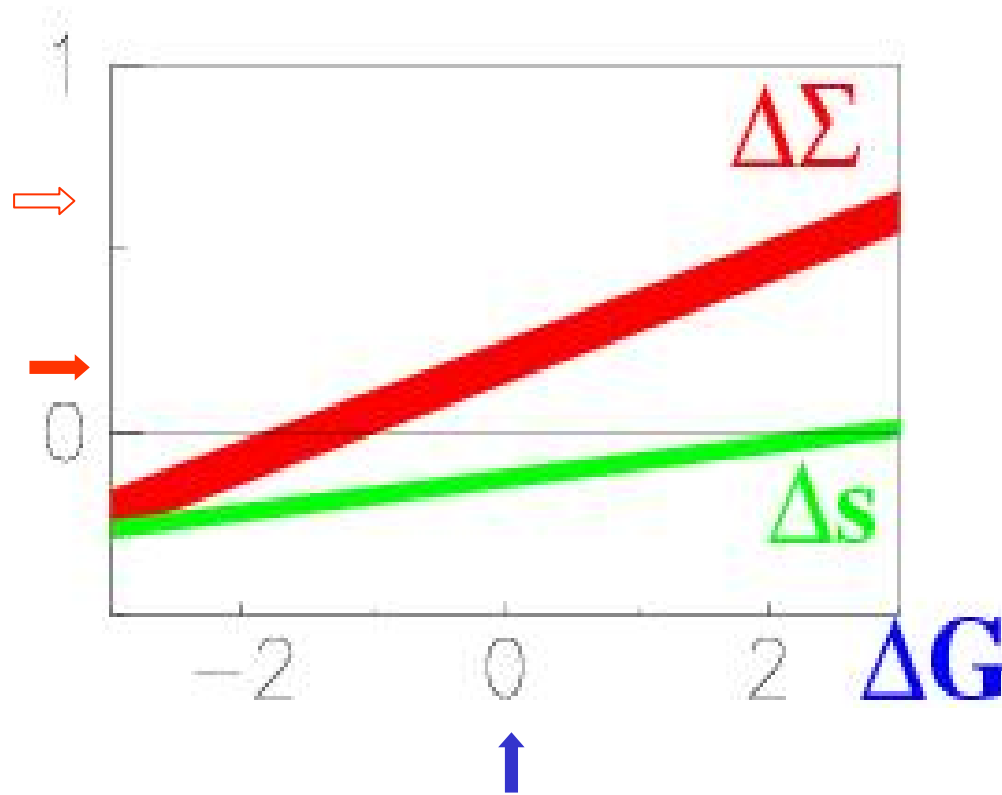
In polarised DIS, one measures flavor singlet axial matrix element

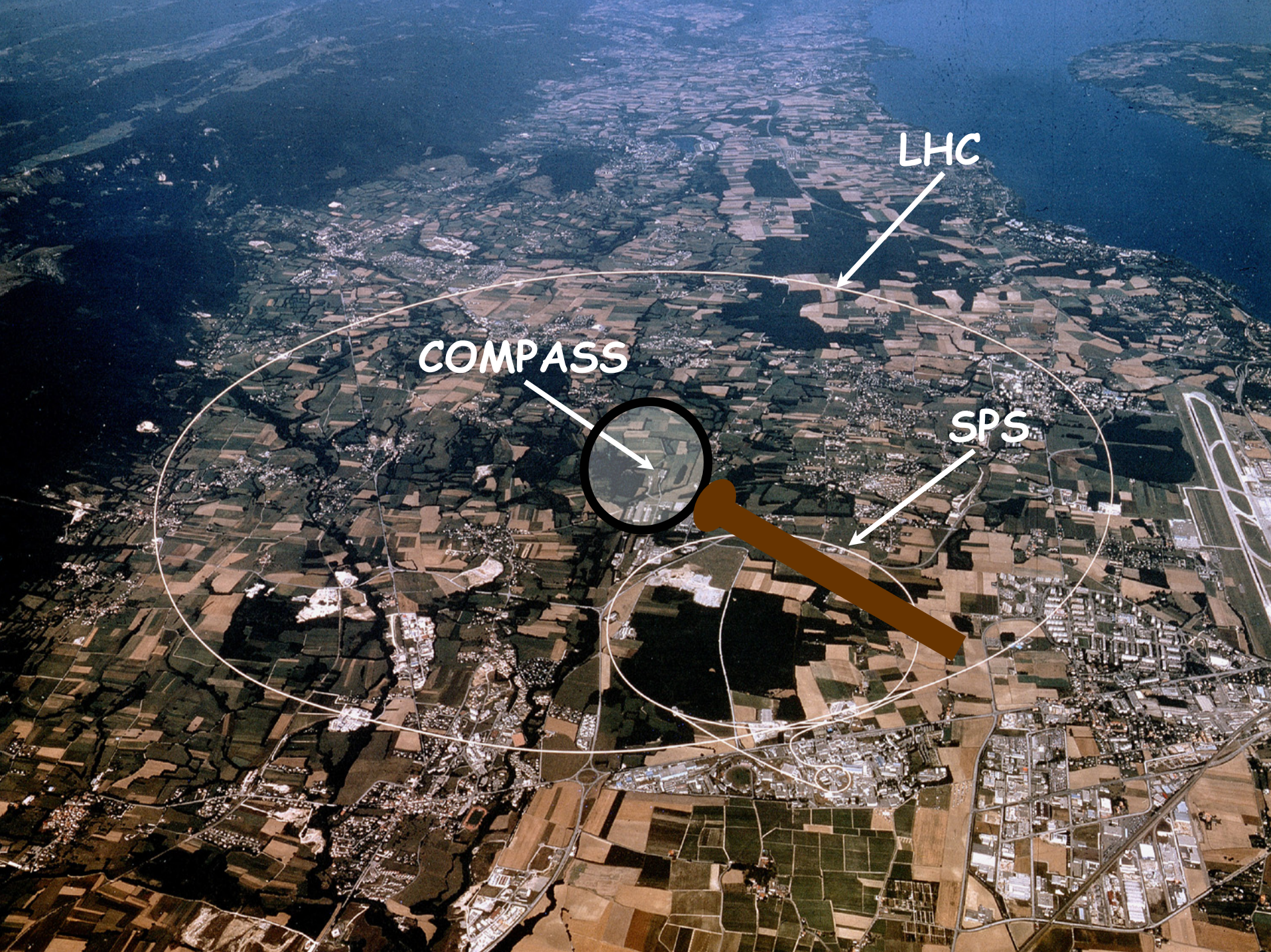
$$a_0 = \Delta\Sigma - (\alpha_s/2\pi)n_f \Delta G$$

All experiments (SLAC, EMC, SMC, SLAC, HERMES) confirm:

$$a_0 \sim 0.1, 0.2$$

Imperative to measure  $\Delta G$

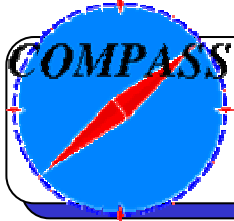




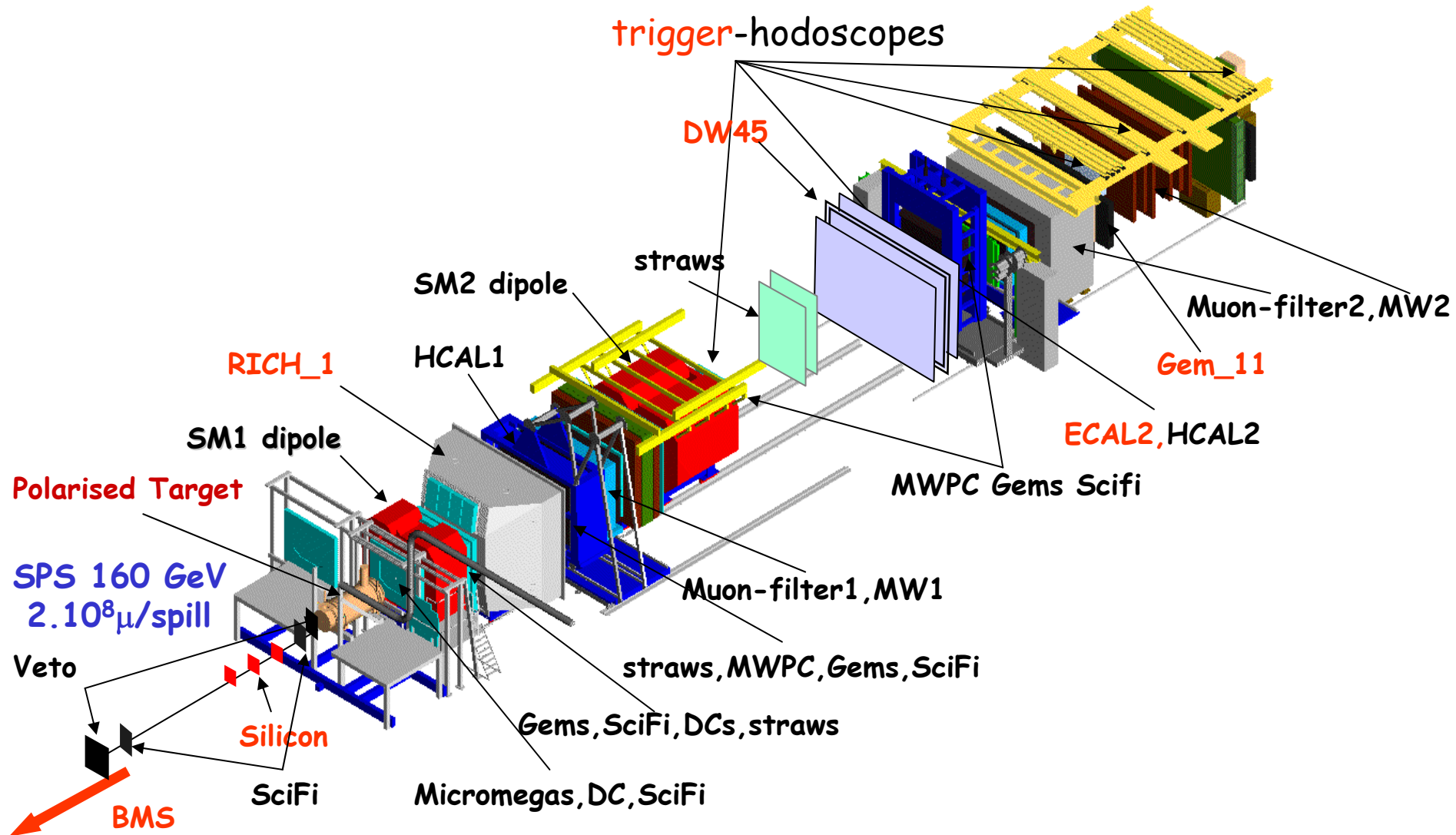
LHC

COMPASS

SPS

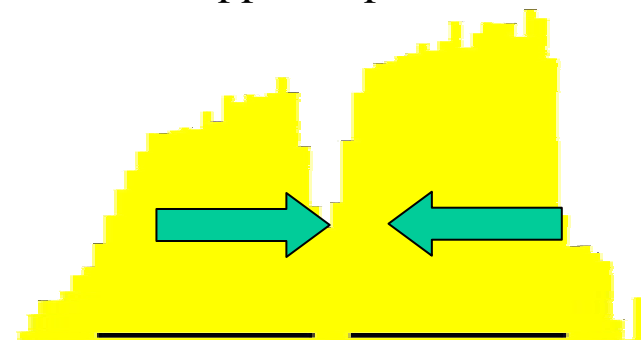
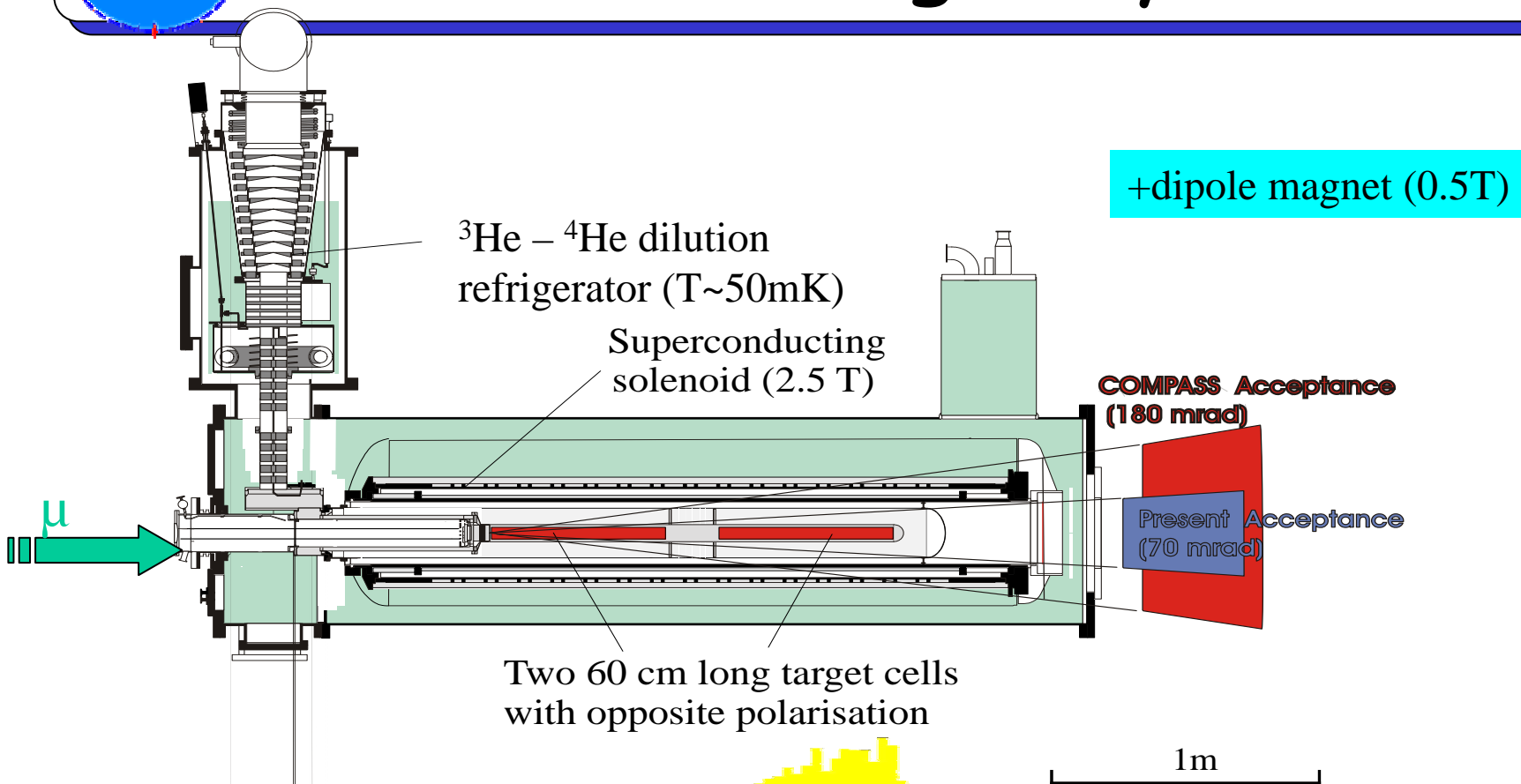


# Spectrometer 2002 -> 2004

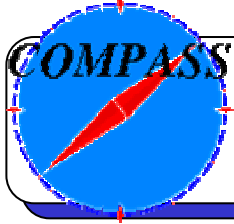




# Polarized target system

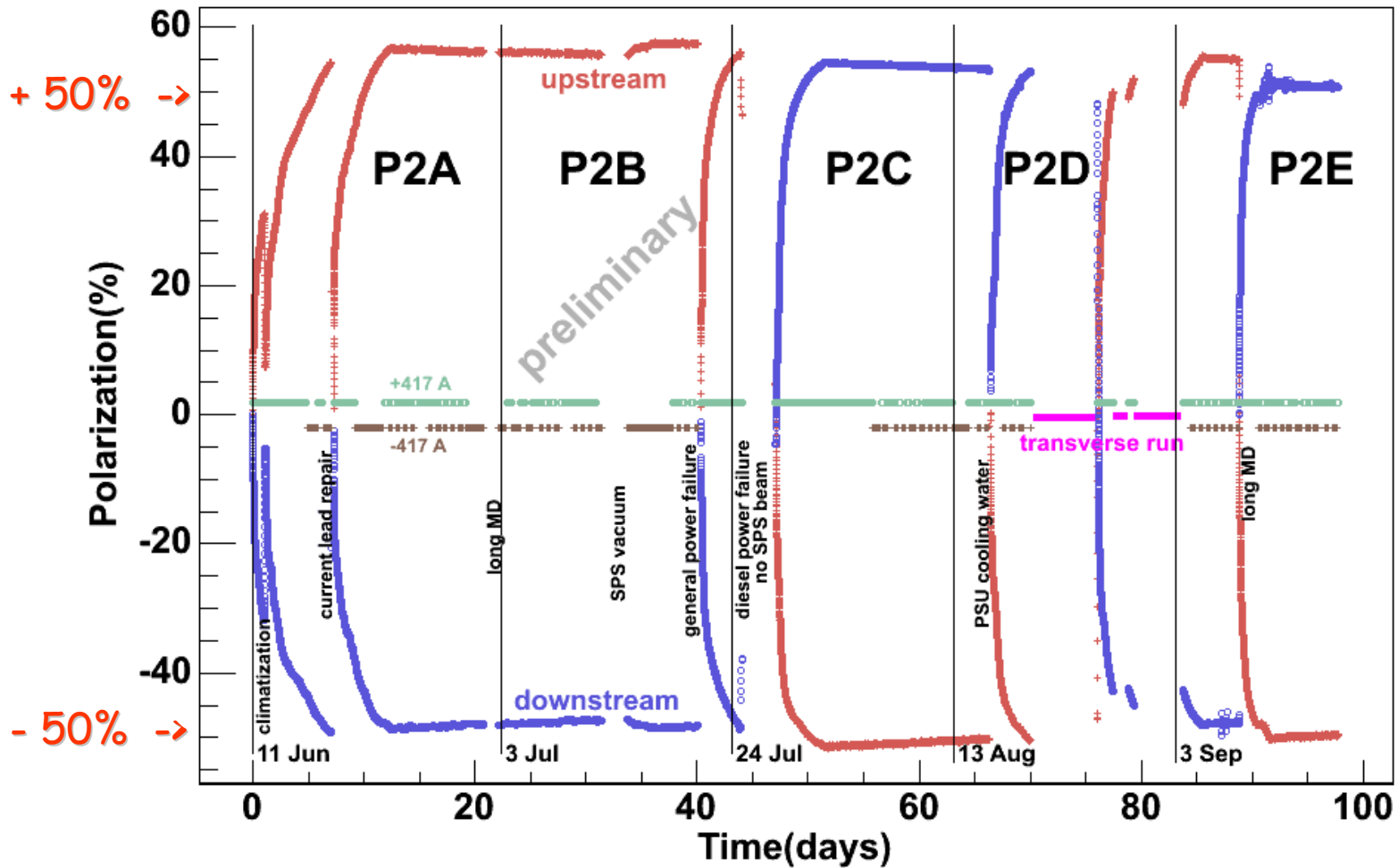


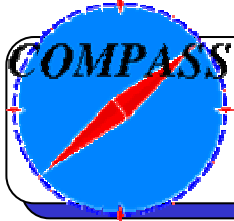




# ${}^6\text{LiD}$ polarisation in 2003

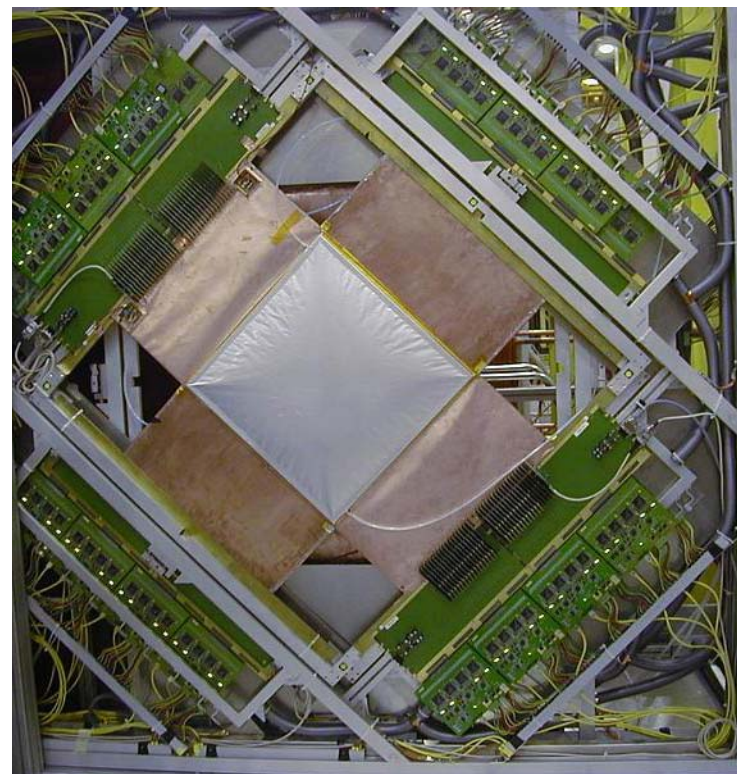
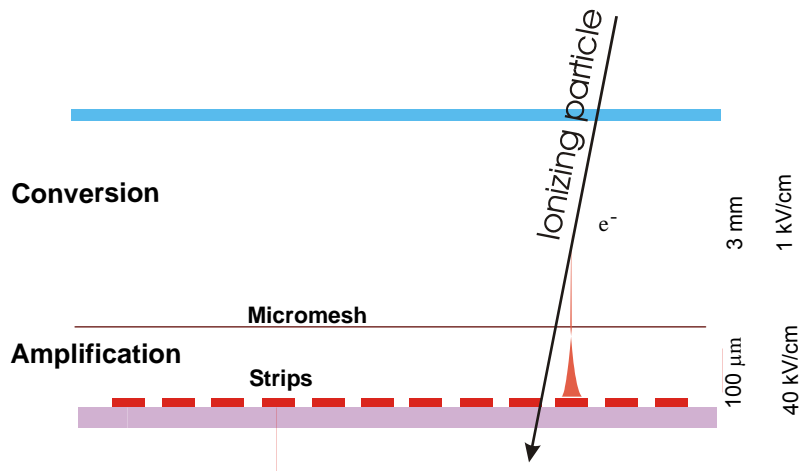
2003 polarization 11 June - 17 September

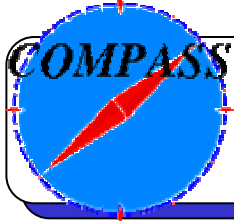




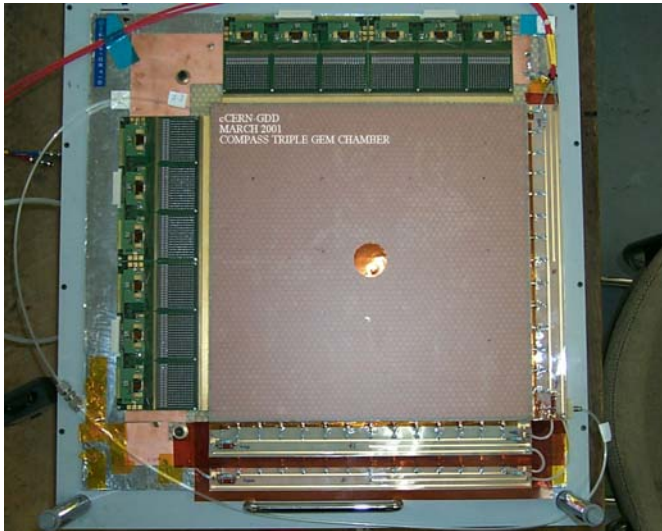
# Micromegas

6 stations, 12 coordinates  
size 40x40 cm<sup>2</sup>  
pitch 360 - 420 μm  
time res. < 10 ns  
space res. 70 μm  
efficiency > 97%  
Ne/C<sub>2</sub>H<sub>6</sub>/CF<sub>4</sub> 80/10/10 %

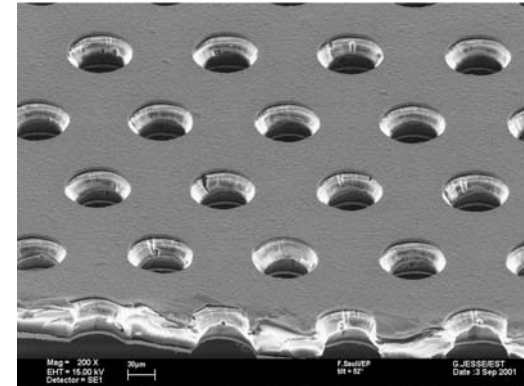
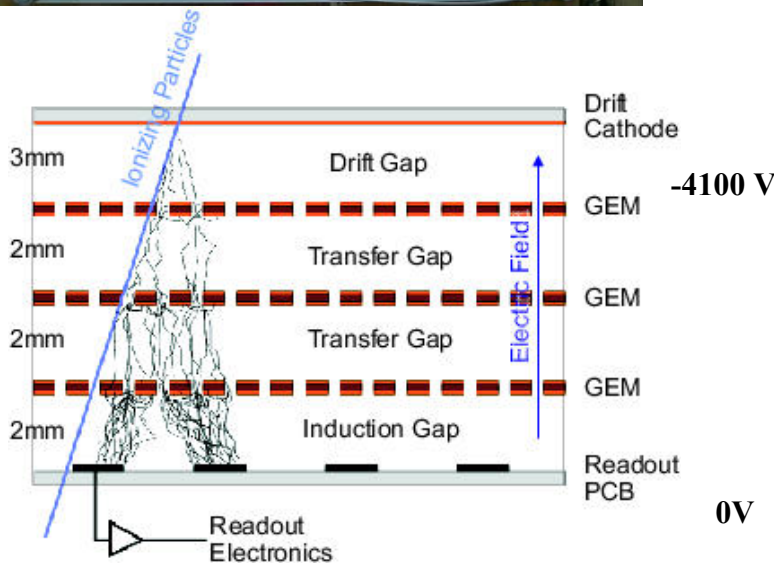


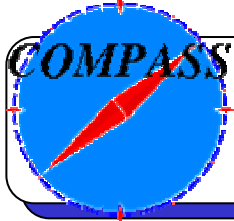


# GEMs



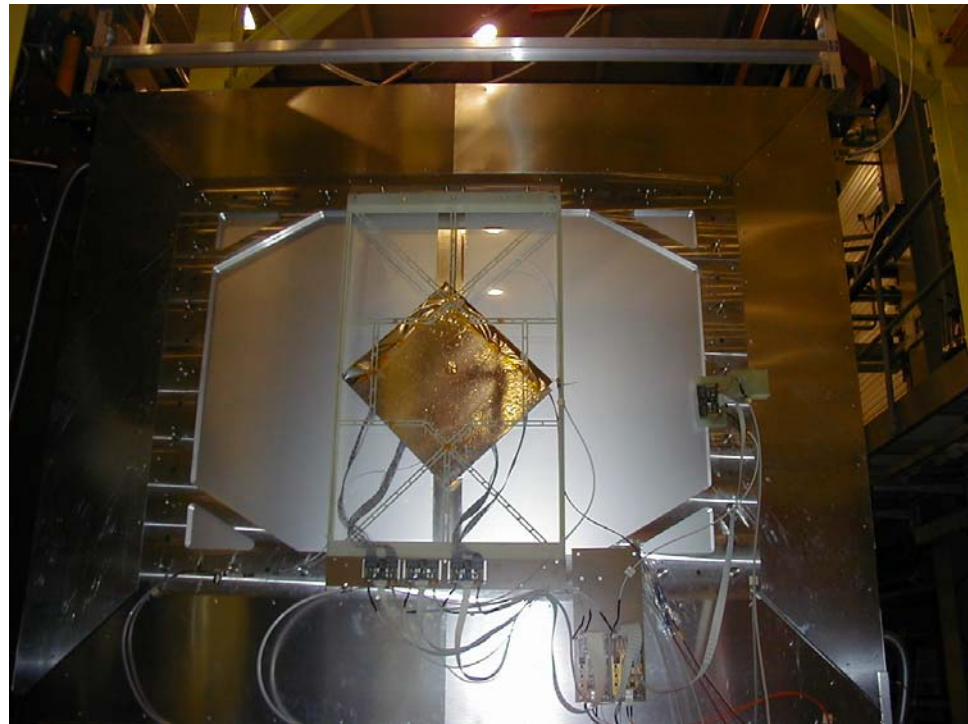
- 20 triple GEMs detectors in 10 stations
- 40 coordinates
- size 30x30 cm<sup>2</sup>
- 12 ns time resolution
- 50  $\mu$ m space resolution
- efficiency ~ 97 %
- Ar/CO<sub>2</sub> 70/30 %

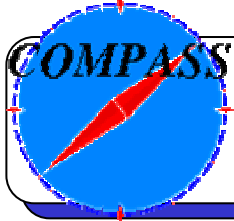




# Large Drift Chambers

- 3 drift chambers
- 24 coordinates
- size 120x120 cm<sup>2</sup>
- 7 mm drift cell
- 170 μm space resolution
- efficiency > 95 %
- Ar/C<sub>2</sub>H<sub>6</sub>/CF<sub>4</sub> 45/45/10 %





# Straws

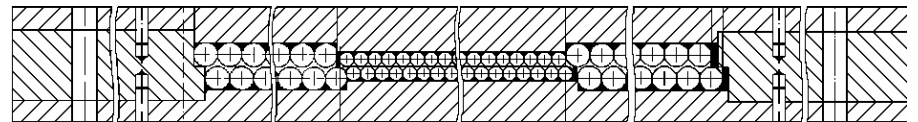
10 mm straws

6 mm straws

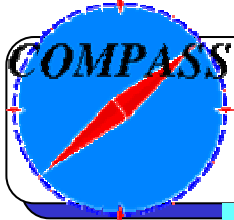
Hole

160 x 230  $\mu\text{m}^2$

10 mm straws

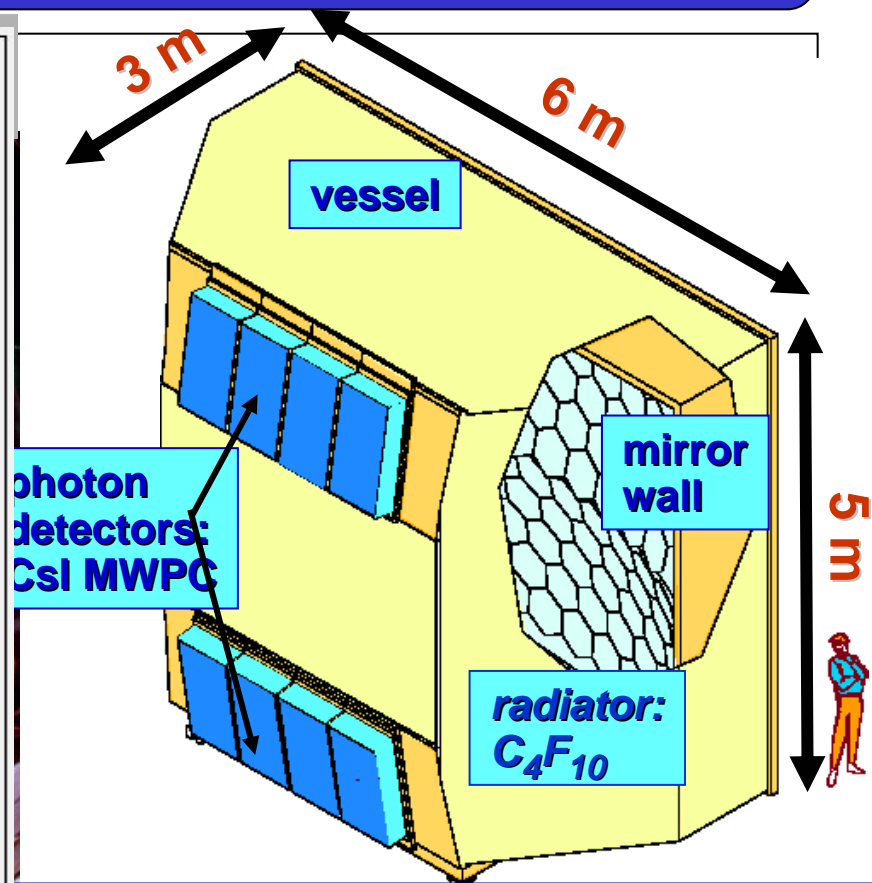
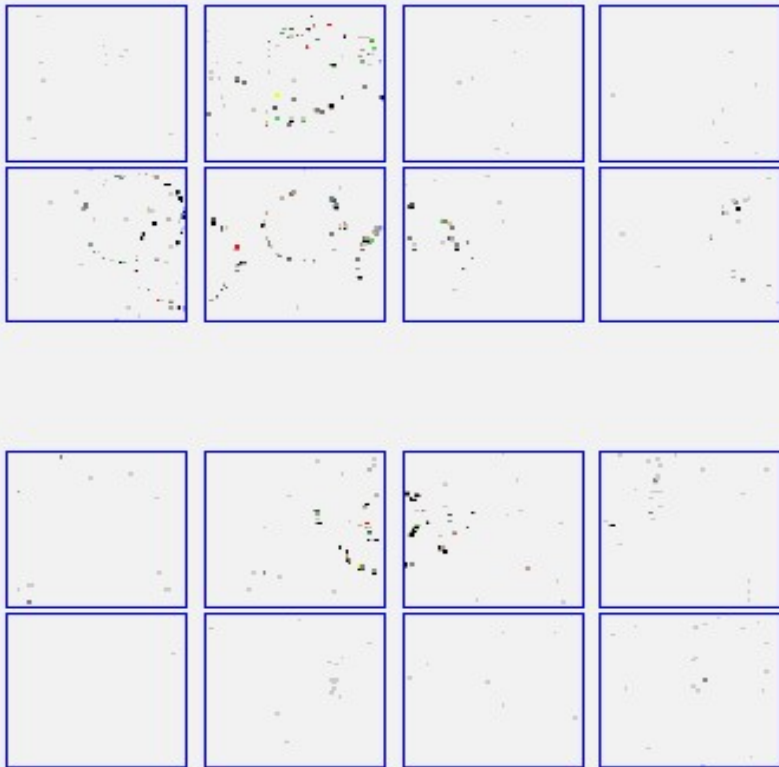


- 15 double layers of 6 and 10 mm straws
- size 325x242cm<sup>2</sup>
- resolution 270  $\mu\text{m}$
- efficiency 85 - 98 %
- Ar/CF<sub>4</sub>/CO<sub>2</sub> 74/20/6 %



# PID with RICH

## Single event



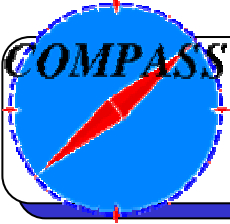
Photon detection

5.3 m<sup>2</sup> MWPCs

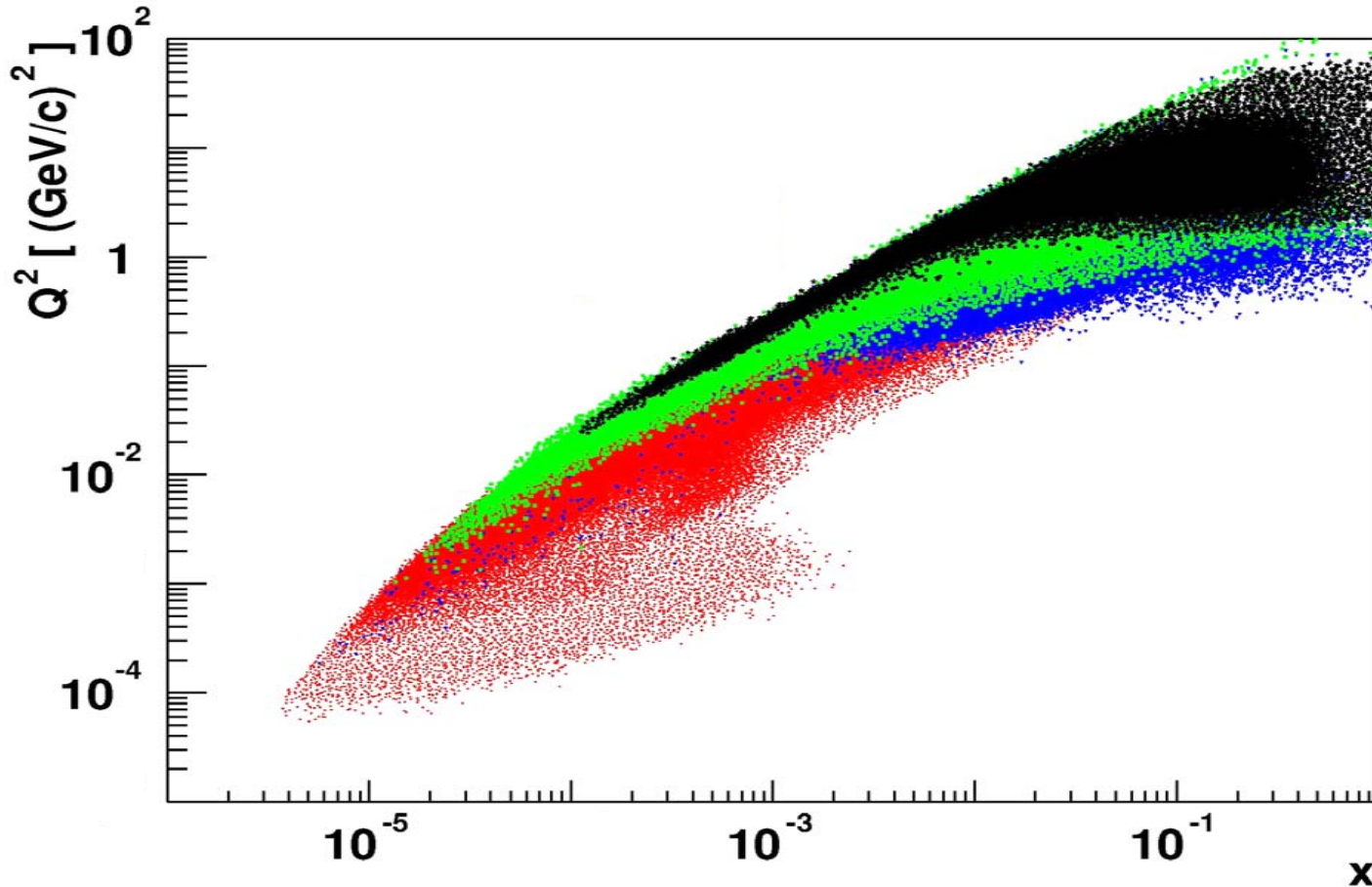
16 CsI Photocathodes

84,000 analog readout channels

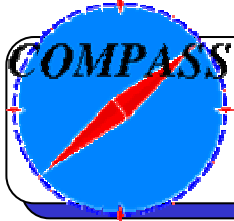
<i>S</i>	detection of	$\sigma = 1.2 \text{ mrad}$
<i>r</i>	VUV photons	$\sigma = 0.4 \text{ mrad}$
<i>p</i>	(165-200 nm)	$n \sim 14$
	$3\sigma \pi / K \text{ sep.}$	up to 40 GeV/c



# COMPASS acceptance



Excellent for non-perturbative & perturbative physics  
- small  $x_{Bj}$  & very small  $Q^2 \rightarrow Q^2 > 100 \text{ (GeV/c)}^2$



# Accumulated data

2002 & 2003:

- 500 TByte Data

- $10^{10}$  Events

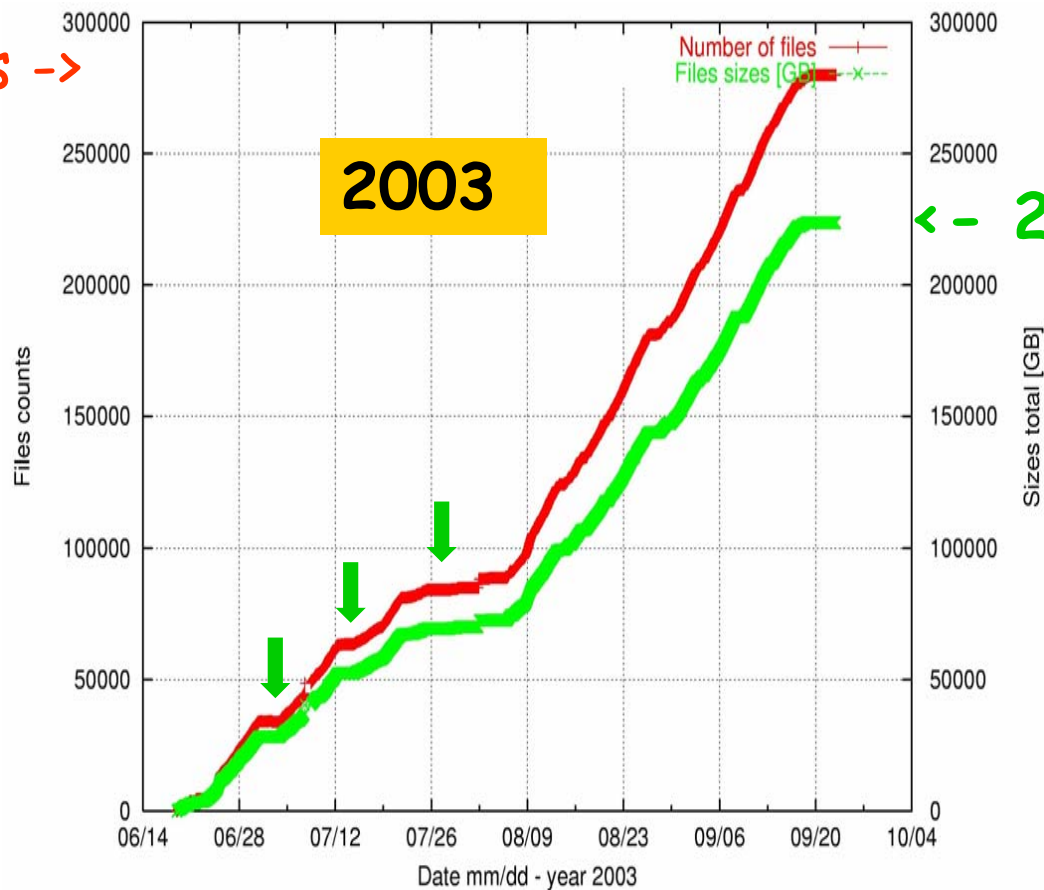
  - longitudinal polarization

- $3 \cdot 10^9$  Events

  - transverse polarization

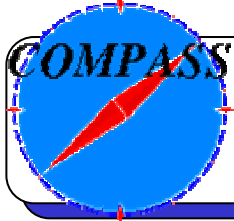
- 0.1% with  $Q^2 > 1 \text{ (GeV/c)}^2$   
(after all cuts)

Files ->



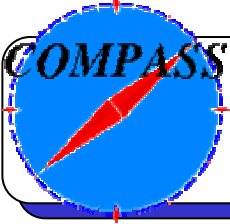
← - 225 Tb





# Physics results 2002 data

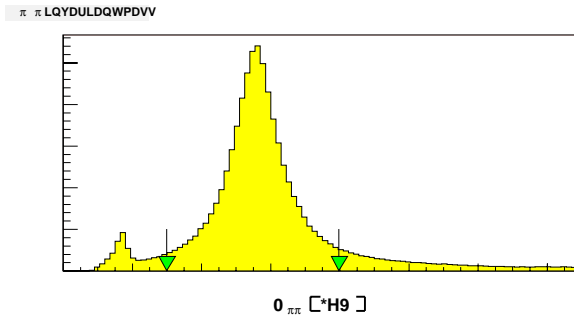
- Vector meson production  $\rho$ ,  $\phi$  and  $J/\psi$ .
- Exclusive  $\rho^0$  production
- $\Lambda$  &  $\bar{\Lambda}$  hyperons, production and polarization
- • **Collins asymmetry** (Transverse spin)
- (Longitudinal spin) :  
Flavour decomposition of polarized PDF
- $A_1^d$
- **Open-charm ( $\Delta G/G$ )**
- **Spin asymmetry from high  $p_T$  hadrons pairs ( $\Delta G/G$ )**



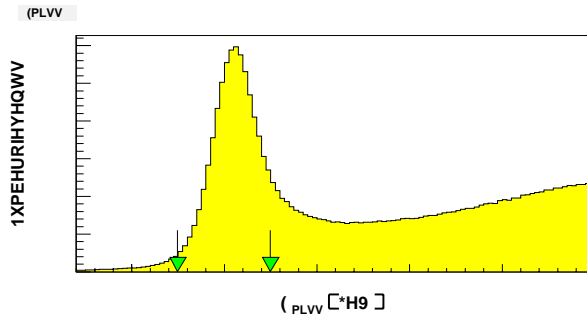
# Exclusive $\rho^0$ production

$\mu$  cuts :  $\nu > 30 \text{ GeV}, E_{\mu'} > 20 \text{ GeV}$

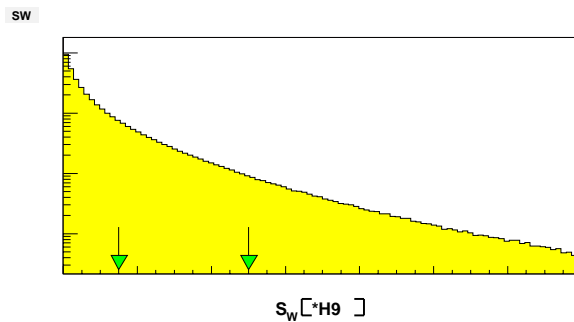
$0.5 < M_{\pi\pi} < 1 \text{ GeV}$



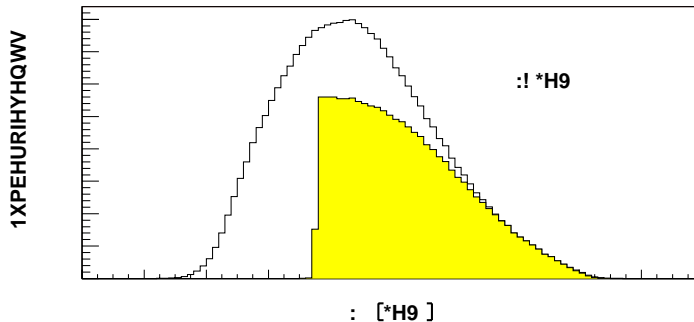
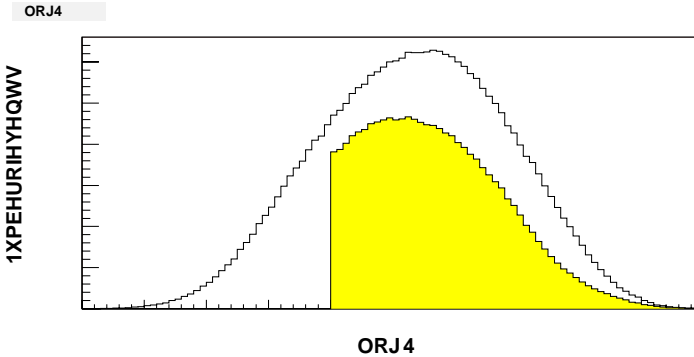
$-2.5 < E_{\text{miss}} < 2.5 \text{ GeV}$

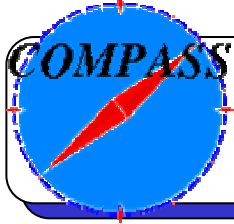


$0.15 < p_{\dagger}^2 < 0.5 \text{ GeV}^2$



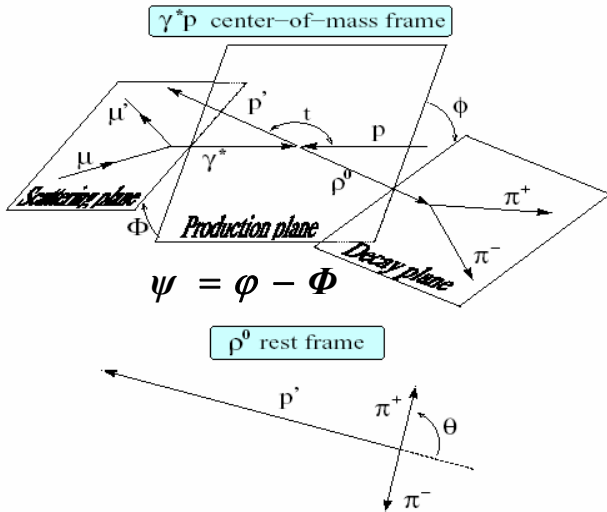
$\text{Log}_{10} Q^2 > -2$





# Exclusive $\rho^0$ production

High precision measurement of spin density matrix element

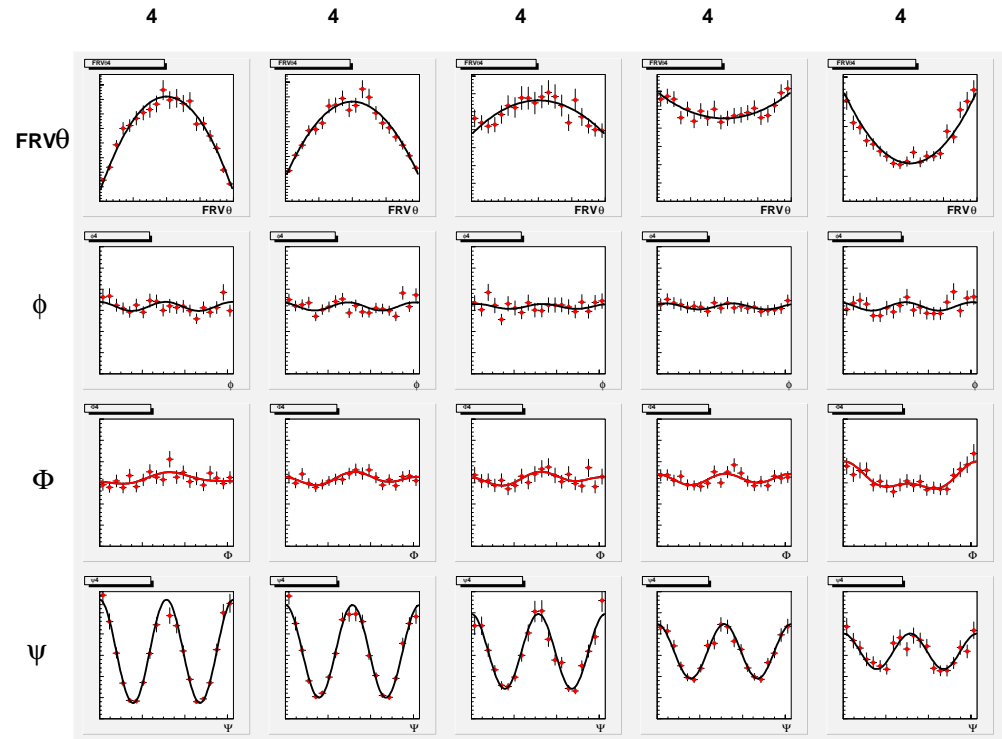


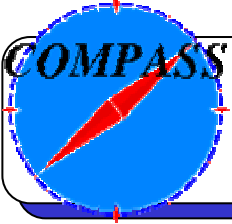
$$W(\cos \Theta) = \frac{3}{4} \left[ (1 - r_{00}^{04}) + (3r_{00}^{04} - 1) \cos^2 \Theta \right]$$

$$W(\psi) = \frac{1}{2\pi} \left[ 1 + 2\varepsilon r_{1-1}^1 \cos 2\psi \right]$$

$$SCHC + \text{parity in } t \rightarrow r_{1-1}^1 = \frac{1}{2} (1 - r_{00}^{04})$$

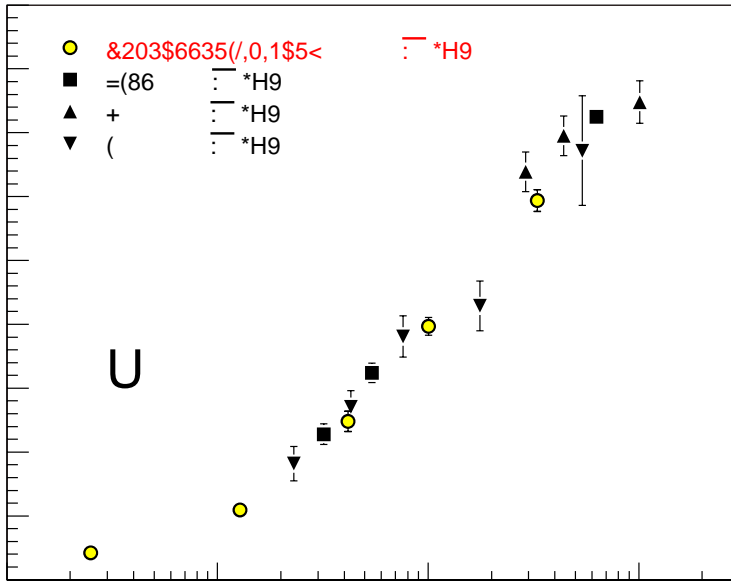
- s-channel helicity conservation
- t-channel natural Parity Exchange



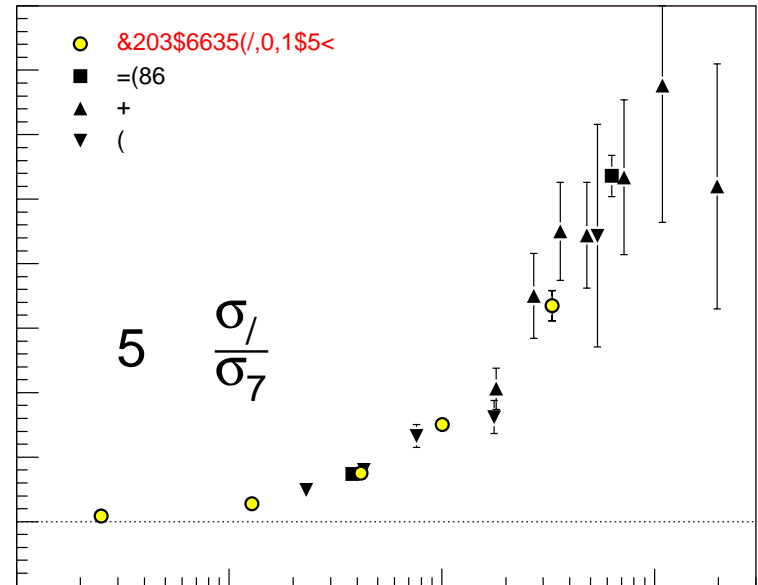


# Exclusive $\rho^0$ production

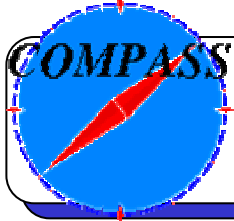
If SCHC  $\rightarrow$  
$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{(\epsilon + \delta)} \frac{r_{00}^{04}}{(1 - r_{00}^{04})}$$



4 \*H9F



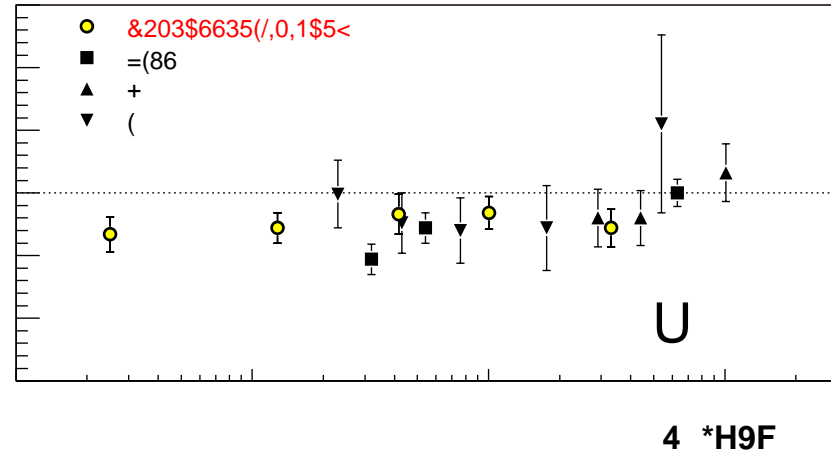
4 \*H9F



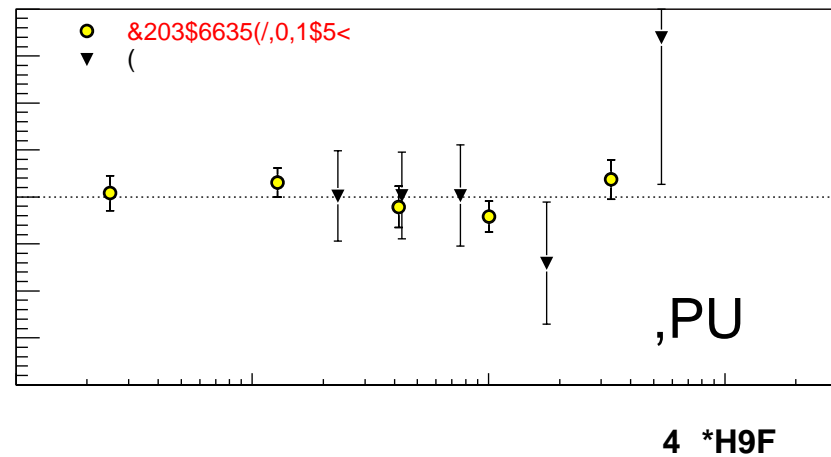
# Exclusive $\rho^0$ production

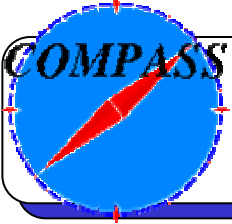
$r_{1-1}^{04} = 0$  if  
SCHC holds

small violation  
of SCHC ?



$r_{1-1}^{03}$  requires  
polarized lepton





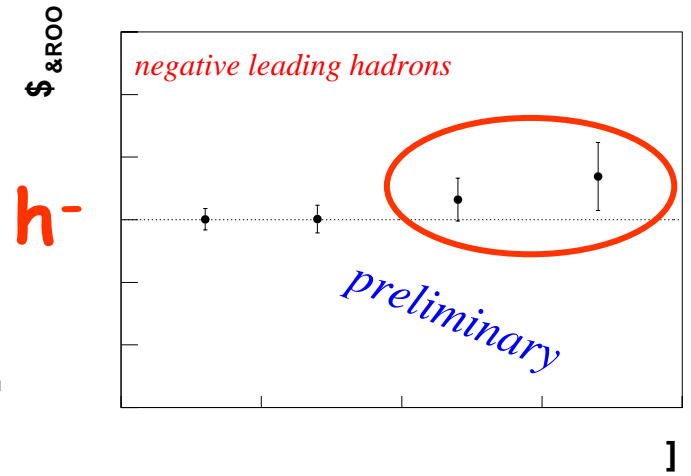
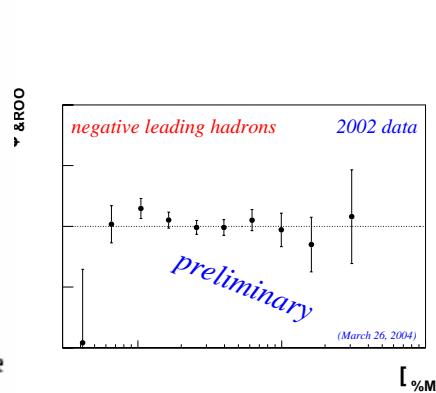
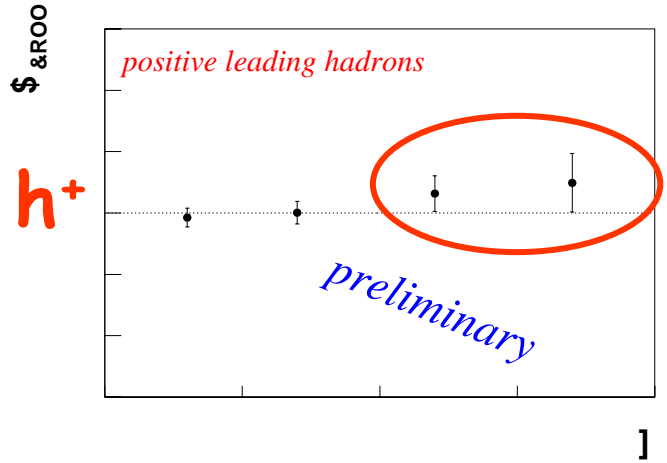
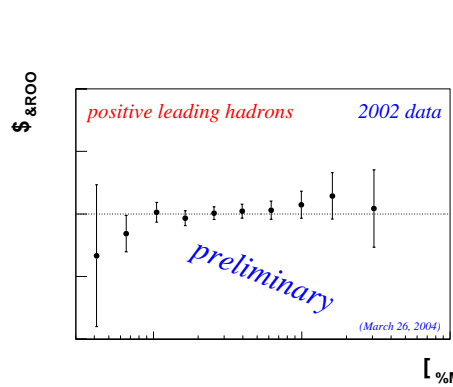
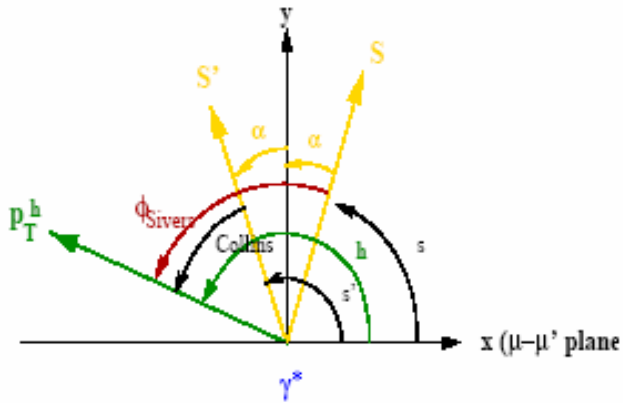
# Transverse spin Collins asymmetry

$$\Phi_C = \Phi_h + \Phi_S - \pi$$

$$A_{\uparrow\downarrow} = A_0 \pm A_1 \sin(\Phi_C)$$

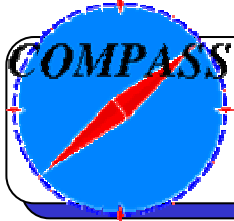
$$A_{\text{Coll}} = A_1 / (D_{NN} \cdot f.P)$$

$$A_{\text{Coll}} \iff h_1^q(x, Q^2)$$



$x_{BJ}$

$z_{had}$



# $A_1^d$ from inclusive scattering

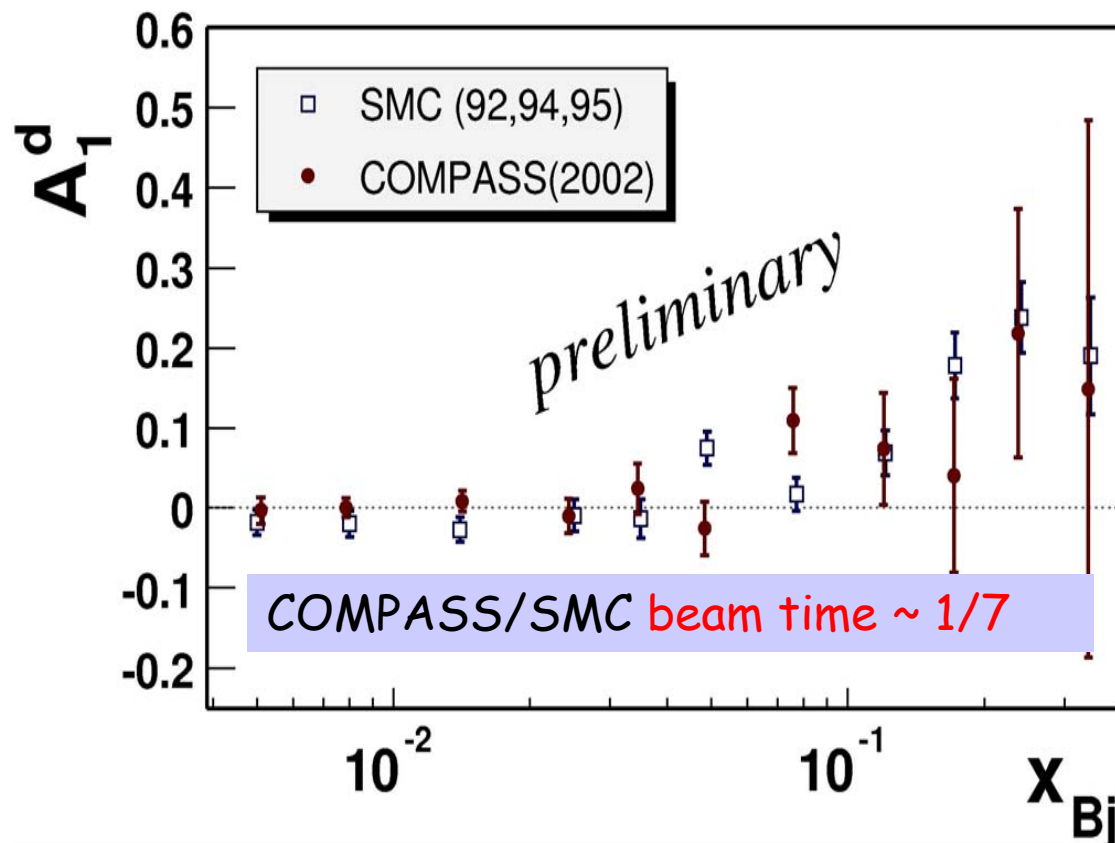
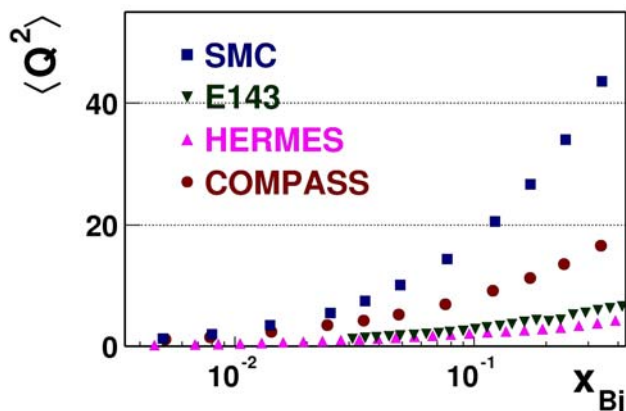
2002 data only

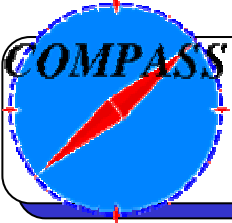
$6.5 \cdot 10^6$  DIS evts

$Q^2 > 1 \text{ GeV}/c^2$

$0.1 < y < 0.9$

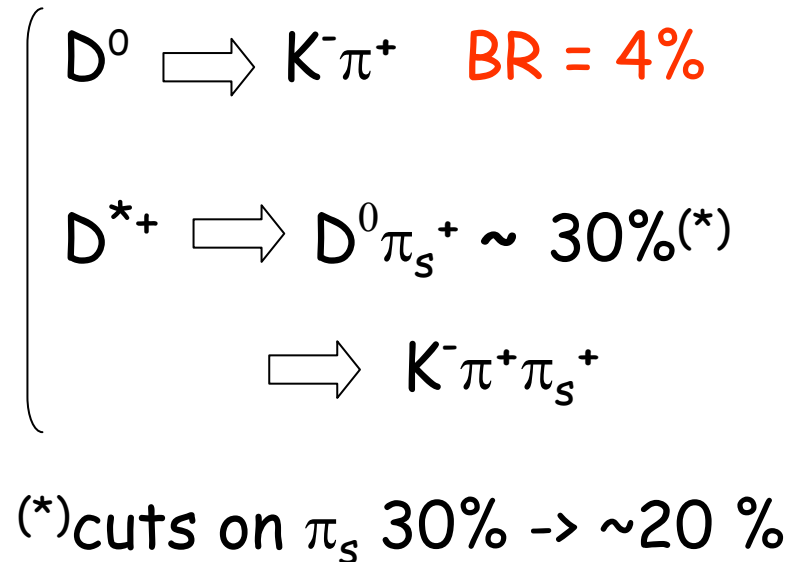
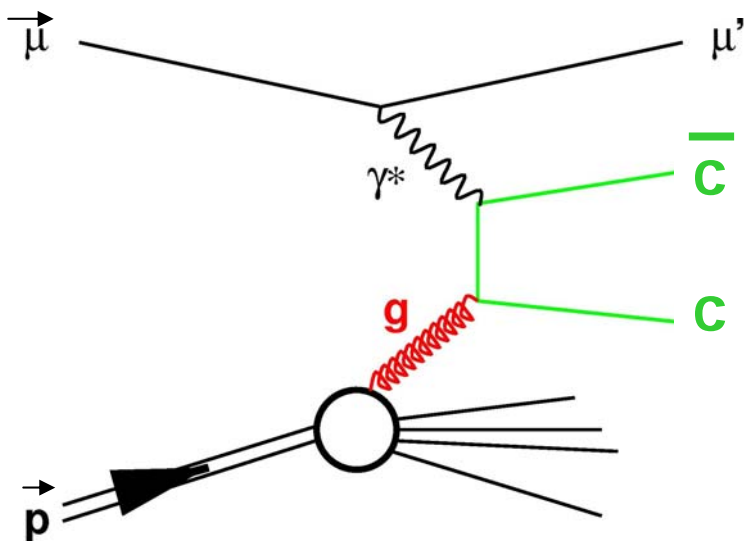
“Longitudinal spin virtual photon asymmetry”



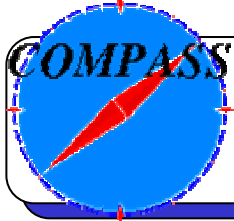


# $\Delta G/G$ determination from open charm

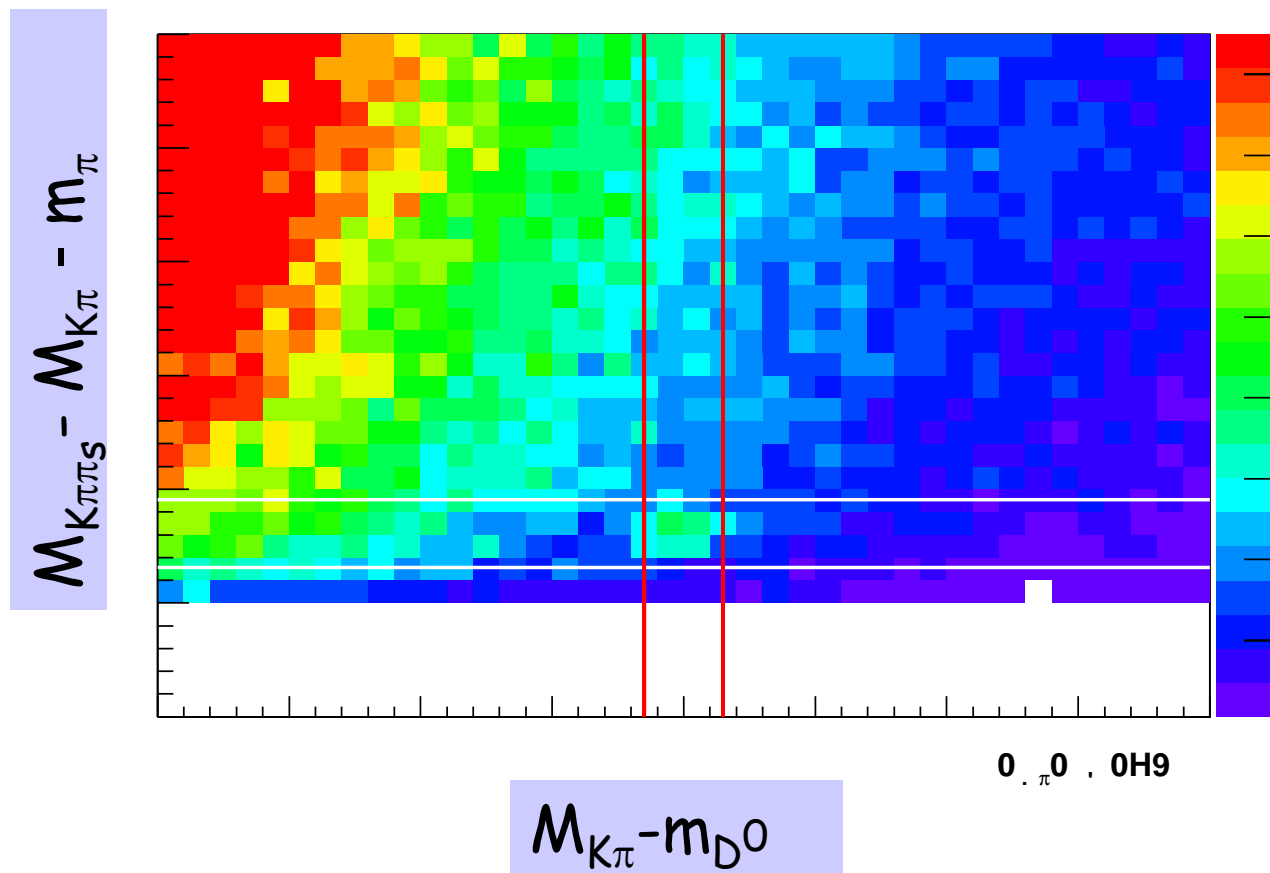
Photon-Gluon-Fusion: 1.2  $D^0$  per PGF  $c\bar{c}$  event

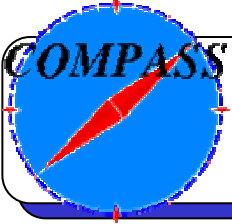




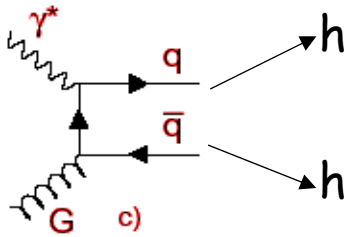


# $\Delta G/G$ determination from open charm

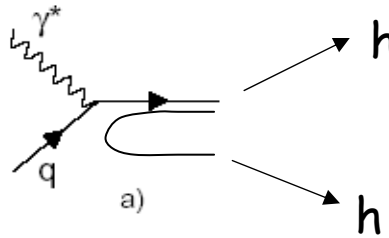




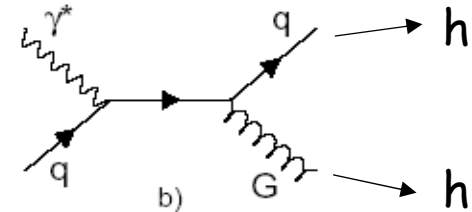
# $\Delta G/G$ from high $p_T$ hadrons pairs



Photon Gluon Fusion  
(PGF)



Leading process



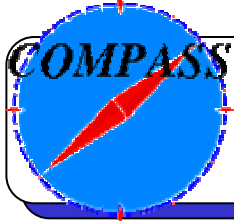
Gluon radiation (Compton)

$$P_{T1}^2 + P_{T2}^2 > 2.5 \text{ GeV}/c^2, P_{T1(2)} > 0.7 \text{ GeV}/c, \text{ no } Q^2 \text{ cut}$$

preliminary (2002 data)

$$A_{\gamma^*}^d = -0.065 \pm 0.036 \text{ (stat)} \pm 0.010 \text{ (syst)}$$

$$\langle x_g \rangle \sim 0.1$$



# $\sigma(\Delta G/G)$ from high $p_T$ hadrons pairs

Monte Carlo study is required to subtract contribution of background before anything can be said on  $\Delta G/G$ .

In progress

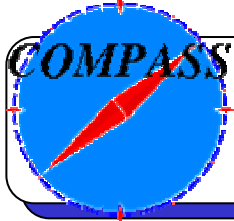
Assuming (Phytia-LO) :  $R_{PGF} \sim \frac{1}{4}$

From preliminary analysis of 2002 data

Thesis Colin Bernet

$$\sigma(\Delta G/G) \sim 0.17$$

$$" \Delta G/G " = 0.**$$



# Projection for $\sigma(\Delta G/G)$

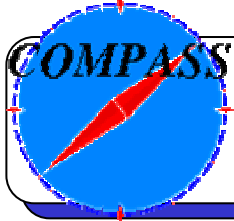
If 2004 as expected, projection for 2002-2004 data:

$$\sigma(\Delta G/G) = 0.05 \text{ high } p_T \text{ all } Q^2$$

$$\sigma(\Delta G/G) = 0.16 \text{ high } p_T \text{  } Q^2 > 1$$

$$\sigma(\Delta G/G) = 0.24 \text{ charm}$$

$\sigma_{\text{syst}}$  from  
resolved  $\gamma$   
+  
LO/NLO ??  
  
HELP from  
theorists !!

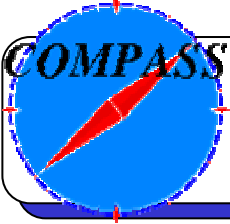


# Running in 2002, 2003 and 2004

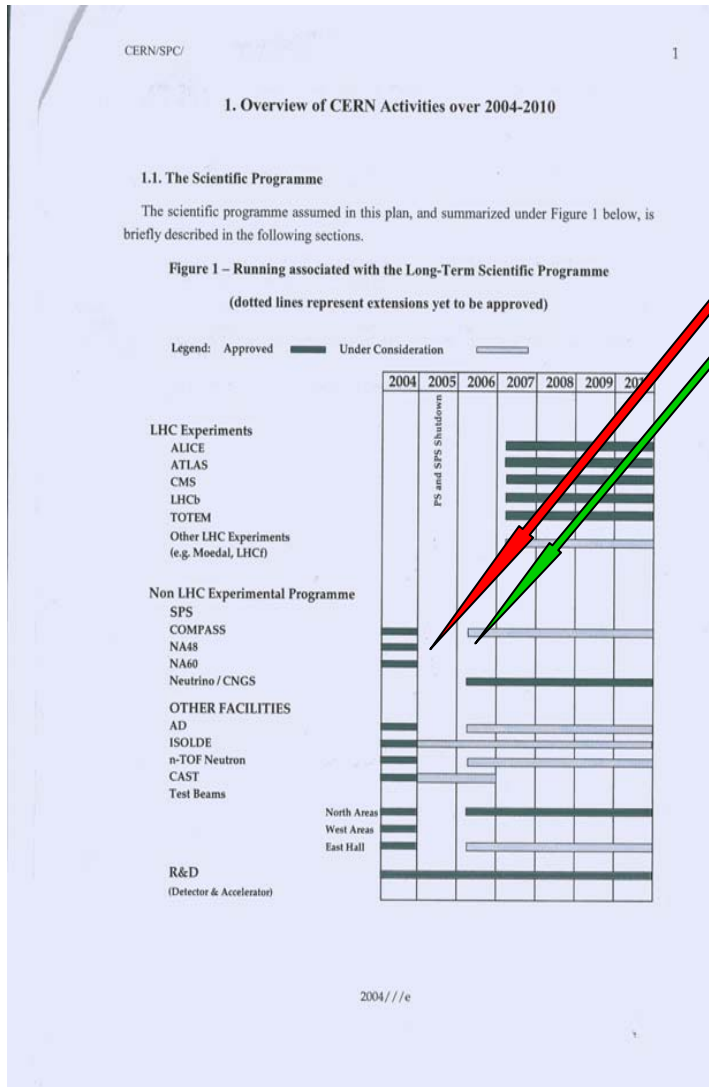
	2002	2003	2004	2004
scheduled	106 d	90 d	110 d	21 d
$\epsilon_{\text{SPS}}$	.89	.63	.80	.80
preparation	~30 d	7 d	7 d	~7 d
$\epsilon_{\text{Spectro}} (3.90_{\text{TGT}})$	.77	.85	.85	.85
data taking	44 d	39 d	62 d	~8 d
(L/T)	33/11	30/9	49/13	

160 GeV muons

hadrons



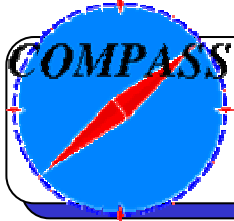
# COMPASS > 2005



SPS off in 2005

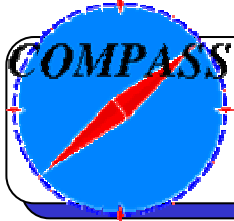
SPS restart in 2006

- COMPASS is in the "5 years mid-term plan" of CERN
- Principal SPS users (apart LHC) are neutrinos/CNGS and COMPASS



# COMPASS > 2010 (Villars/SPSC)

- Upgrades of the PS/SPS complex R. Garoby
- Possible upgrades of M2 and luminosity increase M. Leberig
  
- Unpolarized parton distributions J. Pretz
- Deeply Virtual Compton Scattering M. Diehl & N. D'Hose
- Exclusive production of vector mesons H. Fischer
- Measurements of  $F_2$  and  $F_L$  E.M. Kabuss
- Hadronisation & related topics in SIDIS A. Kotzinian
  
- Shadowing effects in nuclear parton distributions G. Smirnov
- Detector concepts F.H. Heinsius
- Toroidal spectrometer (I. Savin)
- Polarisation observables F. Bradamante
- hadron programme R. Bertini (S.Paul)



# Conclusions

- Muon programme well on the tracks, **will continue beyond 2005**
- **Preliminary longitudinal (and transverse) spin asymmetries**
- **Green light (CERN) for pilot hadron run in 2004**
- **Thinking beyond 2010 (VILLARS) has started !**