G0 experiment Status
Commissioning Run

- Physics case

- Experimental set-up

- First results from the commissioning run

LPSC Grenoble
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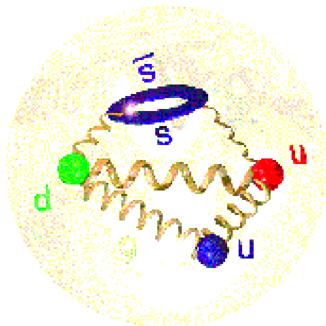
Nucleon Structure and Strangeness



$Proton$ º $uud + \underbrace{g + u\bar{u} + d\bar{d} + s\bar{s} + \ldots}_{\text{« Sea »}}$

$m_u \approx m_d \approx 5$ MeV $m_s \approx 130$ MeV $m_c \approx 1.2$ GeV

Probability of $q\bar{q}$ creation $\propto 1/m_q^2 \Rightarrow$ Sea Quarks ~ *u, d, s, (c,b, t)*

Strangeness in nucleon Þ Study of Sea Quarks

Contribution of the strange quarks to :

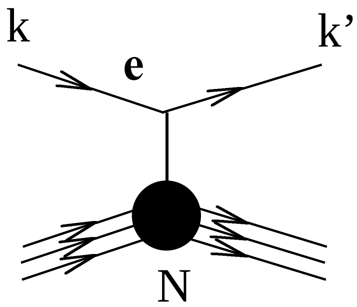
- the mass $\langle N | \bar{s}s | N \rangle \approx$ 30% (πN)
- the spin $\langle N | \bar{s}\, g^m g^5 s | N \rangle \approx$ - 6% (DIS)
- ***the charge & current*** $\langle N | \bar{s}\, g^m s | N \rangle$ (PV elastic)

Form Factors

Sachs form factors :

Charge distribution $\mathbf{G_E(Q^2)}$

Magnetization distribution $\mathbf{G_M(Q^2)}$



$Q^2 = -q^2 = -(k'-k)^2$

$G_X(Q^2) \approx$ Fourier Transform of spatial distribution

$1/Q$ ~ Spatial resolution of the probe

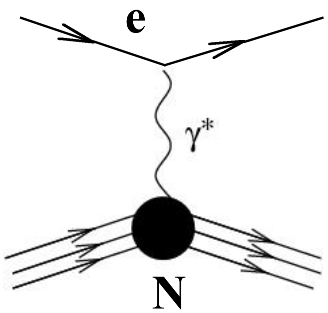
Form factors and global properties (Q^2=0):

$\mathbf{G_E^N}(0) = \mathbf{q_N}$ Charge density $r^2 \equiv -6 \left.\frac{dG_E}{dQ^2}\right|_{Q^2=0}$

$\mathbf{G_M^N}(0) = \mathrm{m}_\mathbf{N}$ Magnetic momentum $m \equiv G_M(0)$

Strange Quark Contribution

Electromagnetic Form Factors :



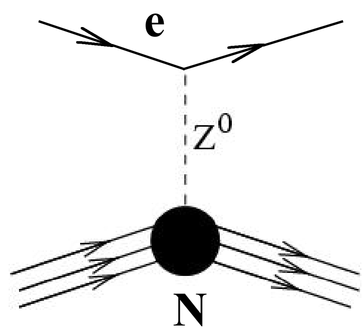
Experimental data on p & n :
Q^2 up to 1 $(GeV/c)^2$

Isospin Symmetry : p↔n ⇔ u↔d

$$G_{E,M}^{\gamma,p} = \frac{2}{3} G_{E,M}^{u} - \frac{1}{3} G_{E,M}^{d} - \frac{1}{3} G_{E,M}^{s}$$

$$G_{E,M}^{\gamma,n} = \frac{2}{3} G_{E,M}^{d} - \frac{1}{3} G_{E,M}^{u} - \frac{1}{3} G_{E,M}^{s}$$

Weak Form Factors :



$$G_{E,M}^{Z,p} = q_W^u \, G_{E,M}^{u} + q_W^d \, G_{E,M}^{d} + q_W^s \, G_{E,M}^{s}$$

G_A^e : Axial Form Factor (Parity Violating term)

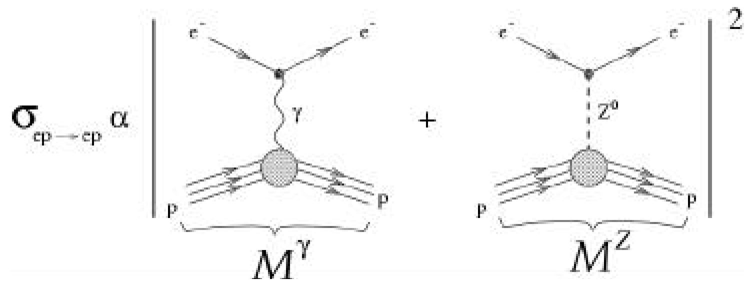
Strange Quarks Contribution :

$$G_{E,M}^{s} = \left(1 - 4\sin^2\theta_W\right) G_{E,M}^{\gamma,p} - G_{E,M}^{\gamma,n} - 4\, G_{E,M}^{Z,p}$$

Experimental Method

Elastic Scattering cross section (*eN*) :

Method used to extract $G_{E,\,M}^{\gamma,\,N}$



For $Q^2 \sim 1\ (\mathrm{GeV}/c)^2$: $M_Z\ /\ M_\gamma \sim 10^{-5}$

Experimental precision : few %

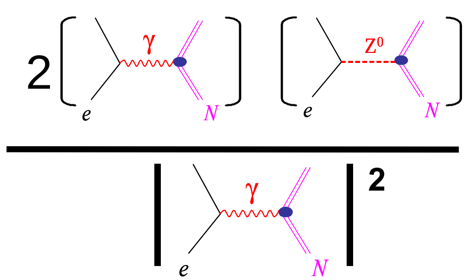
⇒ Extraction of weak terms impossible

Asymmetry with longitudinally polarized electrons :

Parity Violation of Weak interaction

⇒ $\sigma_{\vec{e}p}$ depends on the helicity of the incident electron ($h_e = \pm 1/2$) : σ_+ σ_-

$$A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} =$$



$A_{PV} \sim 10^{-5}$

Experimental uncertainties cancelled in the ratio

(beam current, target density, …)

Nucleon weak form factors

- A_{PV} : linear combination of the Form Factors :

$$A_{PV} = A_{S=0} + h\, G_E^s + c\, G_M^s + x\, G_A^e$$

η, χ and ξ depends on kinematics

- Separation of strange contributions :

At fixed Q^2 and different kinematics

	$Q^2 = 0.5$ $(GeV/c)^2$	A_0(ppm)	h (ppm)	c (ppm)	x (ppm)
1) Proton and small q_e ®	A_F	-16.7	60.8	25.0	1.4
2) Proton and large q_e ®	A_B (LH_2)	-29.0	18.0	40.3	8.5
3) Deuteron and large q_e ®	A_B (LD_2)	-39.8	14.7	9.0	10.1

Þ Extraction of $G_E^s(Q^2)$, $G_M^s(Q^2)$ and $G_A^e(Q^2)$

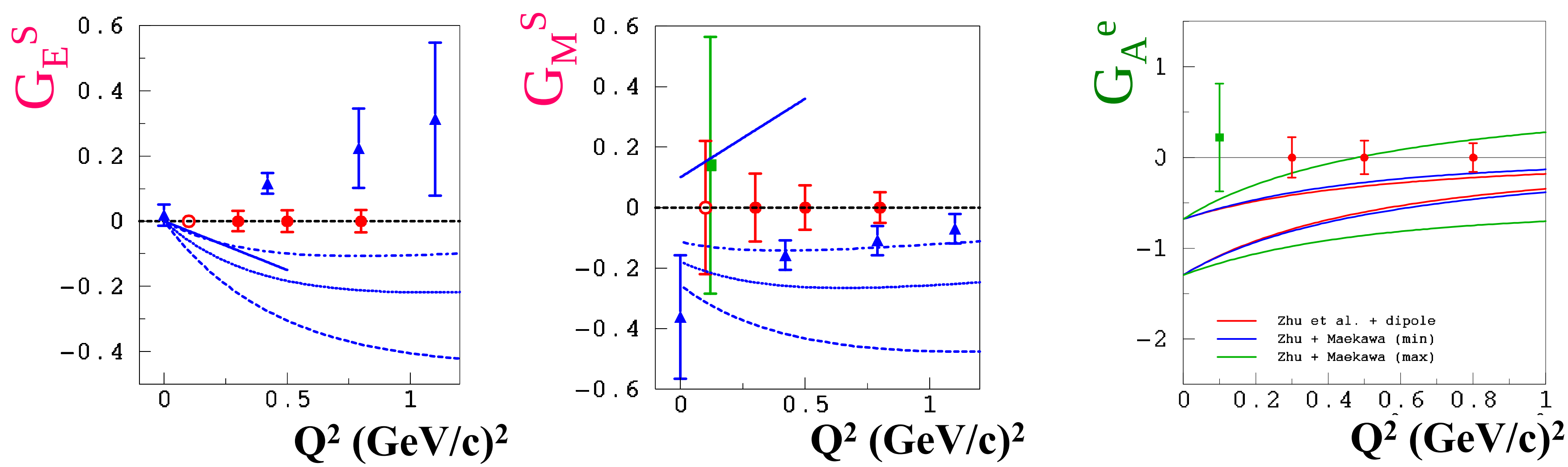
Expected Results

Current Status : G_M^S, G_A^e at Q^2 = 0.1 (GeV/c)^2 SAMPLE (MIT-Bates)

$G_E^S + \alpha G_M^S$: HAPPEX (JLab), PVA4 (MAMI-Mainz)

G^0 : Extraction of $G_E^s(Q^2)$, $G_M^s(Q^2)$ and $G_A^e(Q^2)$

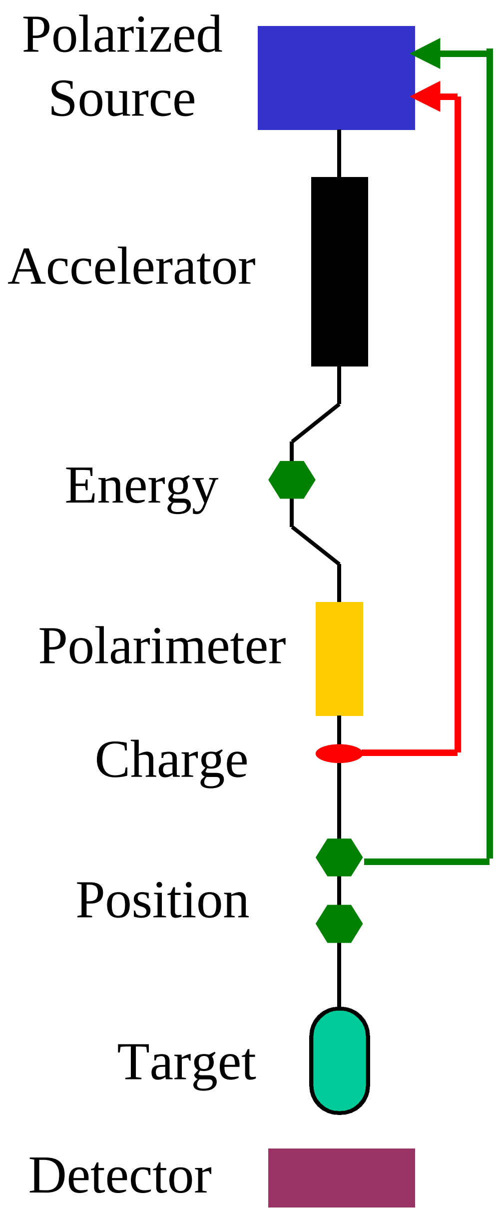
At **Q^2 = 0.3**, **0.5** and **0.8 (GeV/c)^2**



● G^0 proposed ○ HAPPEX2 proposed ■ SAMPLE 2000

- Chiral Pert. Theory (PRC60 (99) 045501)
- Vector Dominance Model (PRC56 (96) 510)
- Lattice QCD (PRD58 (98) 074504)
- Zhu et al., PRD62 (2000) 033008
- Maekawa et al., PLB 488 (2000) 167

Standard Experimental Principle



Polarized Source

Renversal helicity : Pockels cell, Half Wave Plate (In/Out)

High intensity, high polarisation

Magnetic chicane : relative energy measurement

Polarimeter : Compton or Møller

Current monitor : integrated charge (feedback)

Position monitors : Position and angle at the target (feedback)

Target : LH_2 (or LD_2)
Extended target (20 - 40 cm) } High luminosity

Detector : High acceptance and azimutal symmetry

G0 Apparatus

- Electron Beam (CEBAF) :

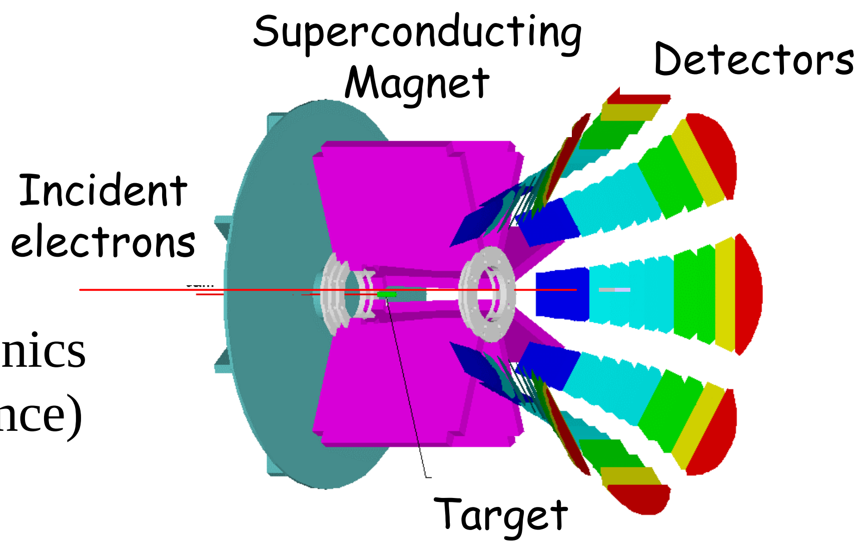
Large Luminosity : 2.1 10^{38} $cm^{-2}s^{-1}$ (40µA, 32ns pulsed beam structure)
High Polarisation ≈ 75%   Helicity Reversal : 30 Hz
Minization of helicity correlated effects :
Use of feedback devices on current and position

- current : $\Delta I/I$ < 1 ppm
- position : Δx < 20 nm

} expexted

- Detection :

Superconducting Magnet : toroidal field
Large acceptance : 0.9 sr
High counting rates : low deadtime electronics
Inelastic/Elastic separation (ToF, coincidence)



G0 Forward Angle Measurement

Scheduled Jan. to Feb. 2004

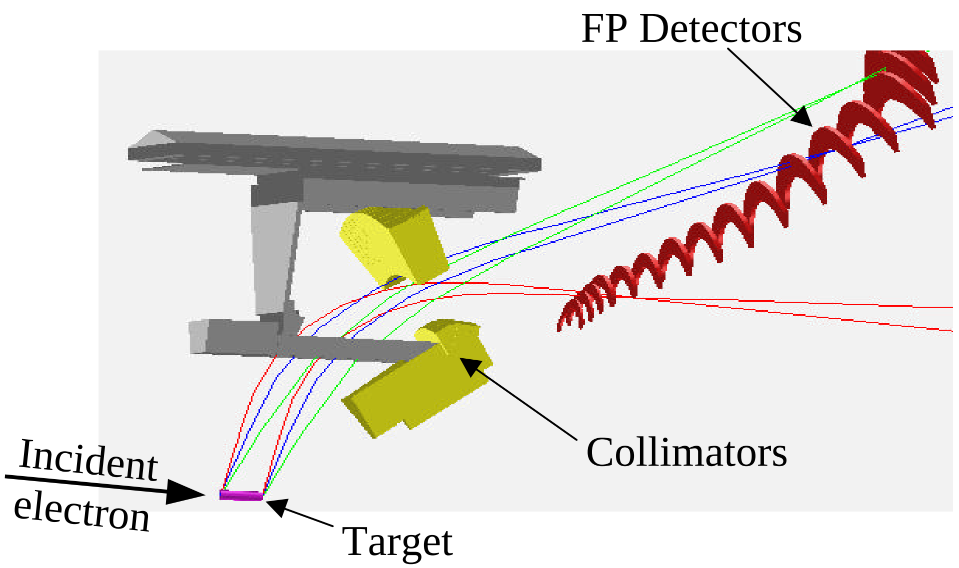
Beam Energy : 3 GeV

Small electron angle θ_e = 6° - 20°

⇒ recoil proton detection (70°)

Q^2 range : 0.1 → 1 $(GeV/c)^2$

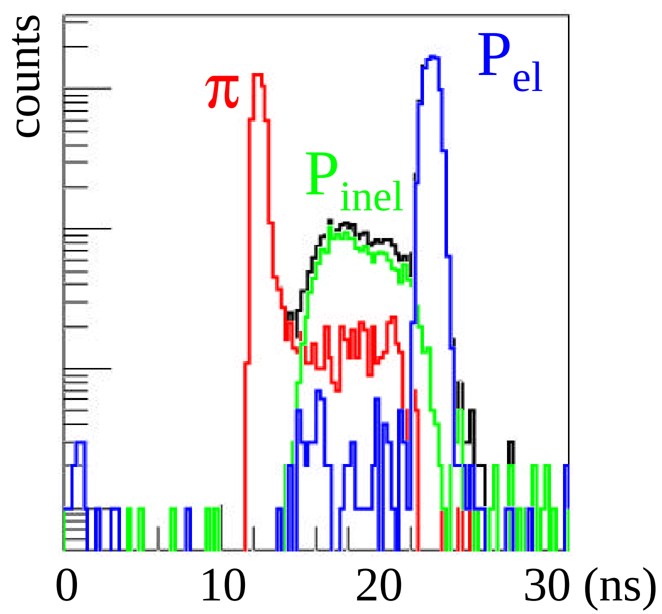
16 iso-Q^2 Detectors



Background removal :

- neutrals : collimators + coincidence front-back scintillators

- charged particles (π, inelastics) :
  Time of Flight spectrum



G0 Backward Angle Measurement

Scheduled late 2004 to 2006

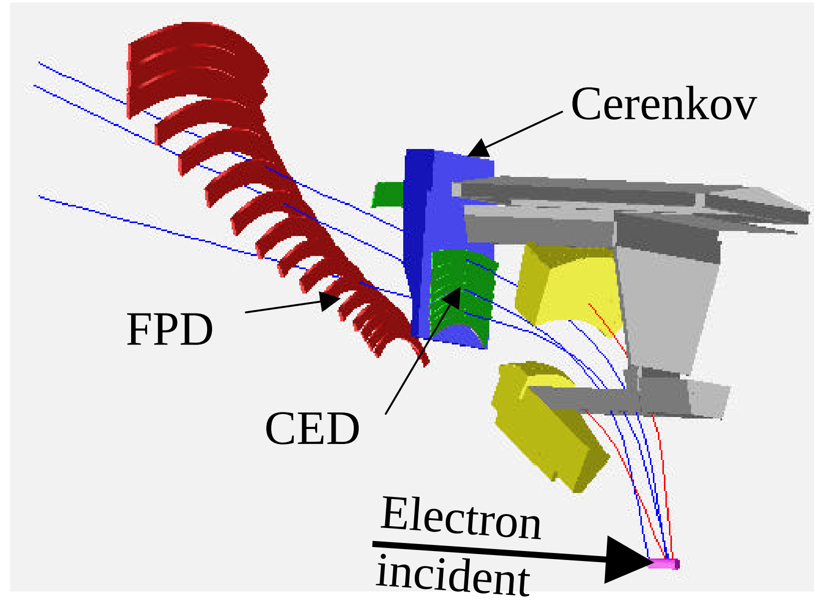
θ_e = 110° ⇒ detection of the electron
Small variation of Q^2

⇒ 3 Beam Energies :

424, 576 and 799 MeV

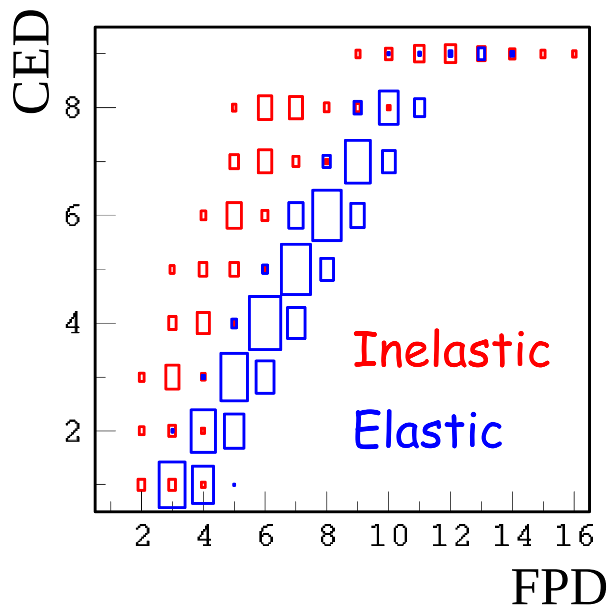
Q^2 : 0.3, 0.5 and 0.8 $(GeV/c)^2$

LH_2 and LD_2 measurements for each Q^2



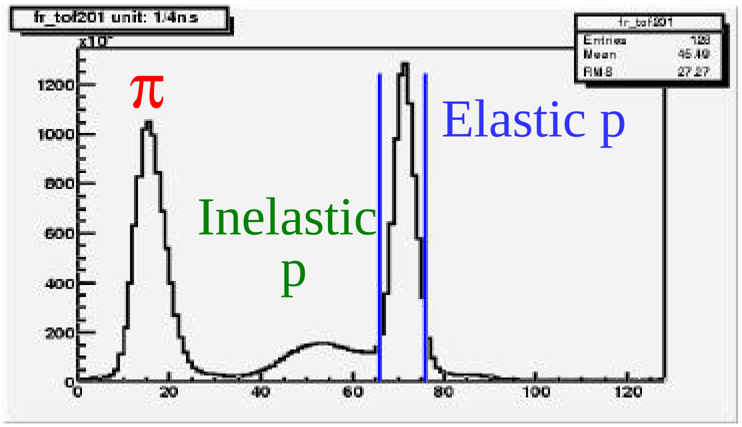
Background removal :

- neutral from target : collimators
- inelastic electrons :
  coincidence FPD-CED scintillators
- π : erenkov detector (reduction 1/100)
  (used for LD_2 measurement)



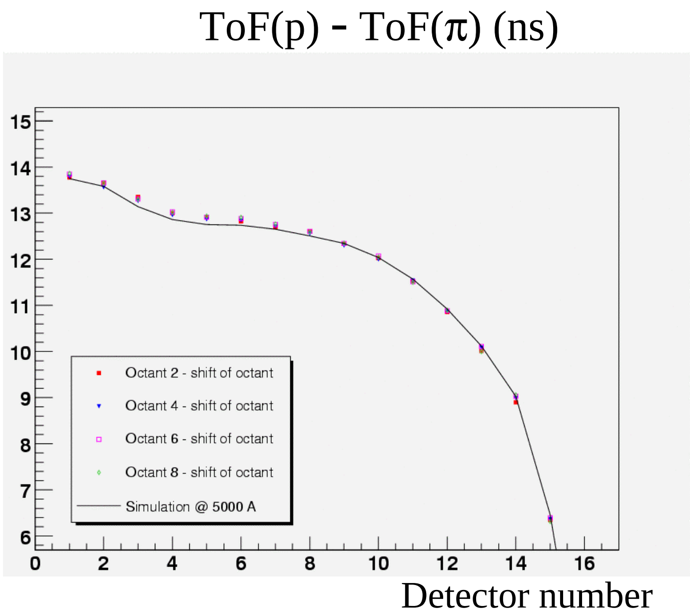
G0 Commissioning Run

- October 2002 to January 2003 + Fall 2003 (forward angle measurement)
- Beam : 40 μA achieved with the specific G^0 beam structure
  feedback system working : ΔI/I < 5 ppm (1/16 of statistic)
  Δx, Δy < 50 nm
- Target and Magnet : target boiling studies, nominal 5000A in magnet achieved
- Shielding : improved along the beam pipe
- Detectors : HV and Threshold settings (gain stability checks)
- Electronics : Studies under progress (time stability, deadtime correction, …)

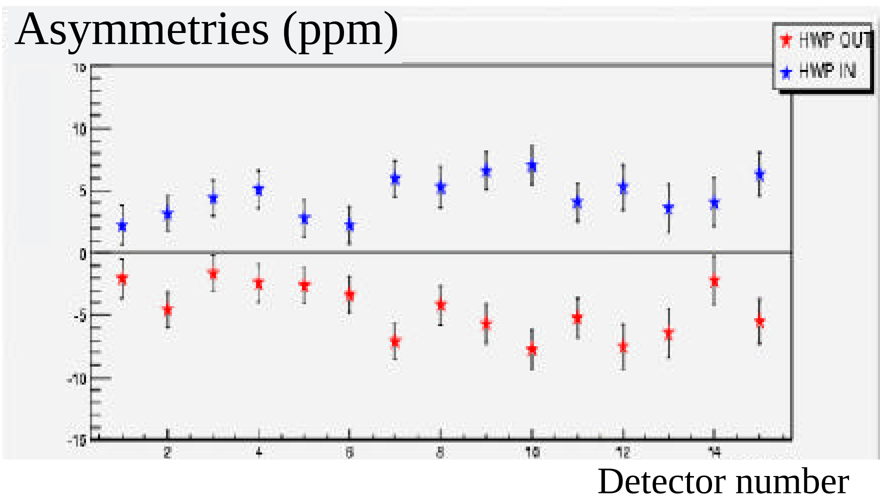


First Results from Analysis

- Comparison Data-Simulation :
  - Inelastic protons estimate :
    Need reduction of target windows contribution
    ⇒ reduce target thickness
  - Q^2 determination
    ⇒ToF difference between P_{el} and π
    (Goal : $\Delta Q^2/Q^2 = 1\%$ ⇒ $\Delta t_{\pi p} = 100$ps)
    Accurate checks of detectors/electronics set-up



- Raw Asymmetries :
  Statistical uncertainty : $\Delta A = 1$ ppm
  (5days : 1/16 of experiment statistic)
  Studies in progress :
  - inelastic contamination
  - electronics response to beam charge asymmetry
    (Goal : $\Delta A_{sys} \sim 1\%$ A_Q)



Summary

- Strangeness in Nucleon

  Measurement of the strange quarks contributions
  to nucleon properties (charge and magnetization)

- Large experimental effort

  HAPPEX (JLab), PVA4 (Mainz), SAMPLE (Bates), G^0 (JLab)

- G0 Experiment :

  First extraction of $G_E^s(Q^2)$, $G_M^s(Q^2)$ and $G_A^e(Q^2)$ individually
  for Q^2 = 0.3, 0.5 and 0.8 $(GeV/c)^2$

  Commissioning results demonstrate a good understanding of
  Beam properties, detector and electronics response
  Physics analysis under way