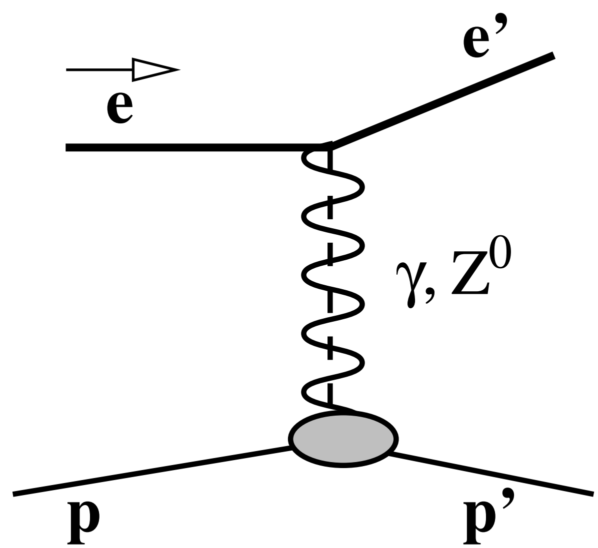
HAPPEX II

E99-115

Constraining the nucleon strangeness radius with parity violating elastic e-p scattering at low Q^2



Spokespersons: K. S. Kumar D. Lhuillier

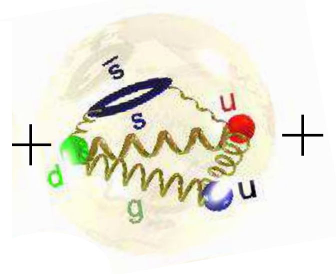
Hall A collabaration experiment

OUTLINE

- Physics motivation
- Experimental design
- Systematics
- Summary

Strangeness in the nucleon

Nucleon = 

$+$ 

$+$ •••

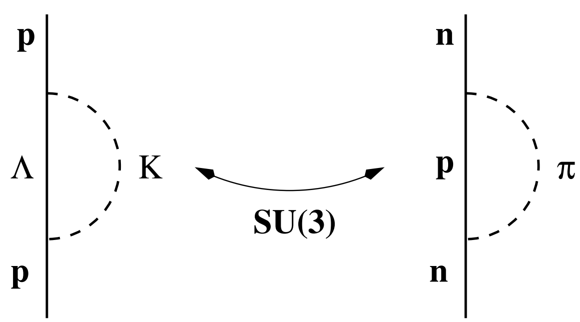
Valence + quark-gluon sea

Does strangeness play a role

in the ground state of the nucleon?

No valence contribution

→ **Unique and pure probe of the sea**



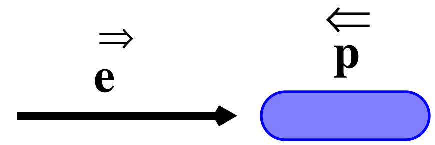
SU(3) image of the π-loop contribution in G_E^n , decorrelated from the quarks contribution.

Strange Matrix Elements

- **<u>Lepton deep inelastic scattering:</u>**

  $\langle N|\bar{s}\gamma_\mu\gamma_5 s|N\rangle$ **Axial vector matrix element.**

  Sea contributes to the spin, Δs~ - 10% **[SU(3)]**



$$A = \frac{\sigma_{\uparrow\uparrow} - \sigma_{\uparrow\downarrow}}{\sigma_{\uparrow\uparrow} + \sigma_{\uparrow\downarrow}}$$

- **<u>π-N scattering:</u>**

  $\langle N|\bar{s}s|N\rangle$ **Scalar matrix element**

  s quarks = 15 % of the mass **[Many assumptions]**

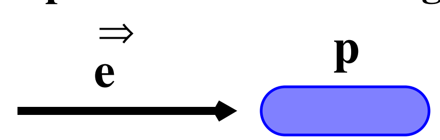
- **<u>Vector matrix element</u>?** $\langle N|\bar{s}\gamma_\mu s|N\rangle$

  Contribution to charge and current distributions

  Clean observables of the strangeness of the nucleon

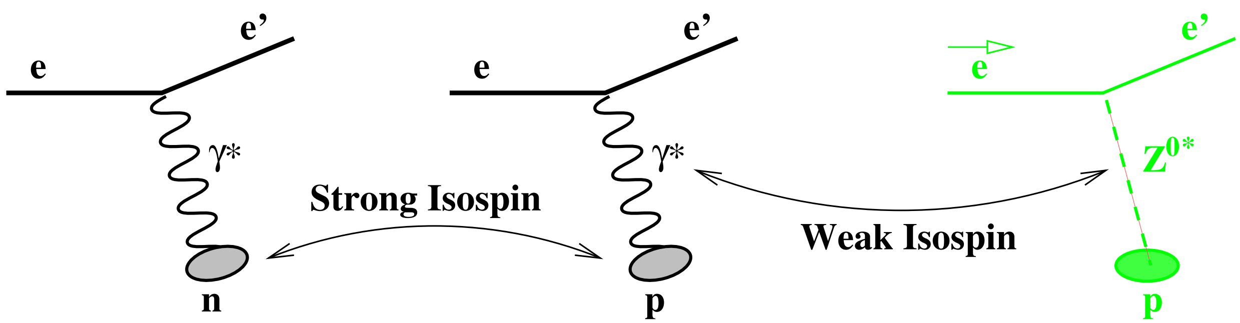
  [Assumes only isospin and Standard Model]

Lepton elastic scattering



$$A = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}}$$

Parity Violating Electron Scattering



Assuming three flavor degrees of freedom:

$$G_p^Z = \frac{1}{4}(1 - 4\sin\Theta_W)G_p^\gamma - G_n^\gamma - \boxed{G^s}$$

$$\sigma = \left|M_\gamma + M_Z\right|^2 \qquad A = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow} \sim \frac{M_Z}{M_\gamma} \sim 10^{-6} \quad (\mathrm{Q}^2 = 0.1\ \mathrm{GeV}^2)$$

$$A^{PV} = -\frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \times \left\{ (1 - 4\sin\Theta_W{}^2) - \frac{\varepsilon G_E^p\,(G_E^n + G_E^s) + \tau G_M^p\,(G_M^n + G_M^s) - \cancel{(1 - 4\sin\Theta)\varepsilon' G_M^p\, G_A^p}}{\varepsilon G_E^{p\,2} + \tau G_M^{p\,2}} \right\}$$

Experimental Status

- **SAMPLE:** G_M^s **at backward angle,** $Q^2 \sim 0.1\, GeV^2$

$$G_M^s = 0.23 \pm 0.37(stat) \pm 0.15(syst) \pm 0.19(theo)$$

$\longrightarrow$ **No large μ_s**

- **HAPPEX:** **Linear combination** $G_E^s + 0.39 G_M^s$ **at** $Q^2 \sim 0.48\, GeV^2$

$$G_E^s + 0.39 G_M^s = 0.023 \pm 0.034(stat) \pm 0.022(syst) \pm 0.026(theo)$$

$\longrightarrow$ **Fast fall off with Q^2, cancellation or small strange effect.**

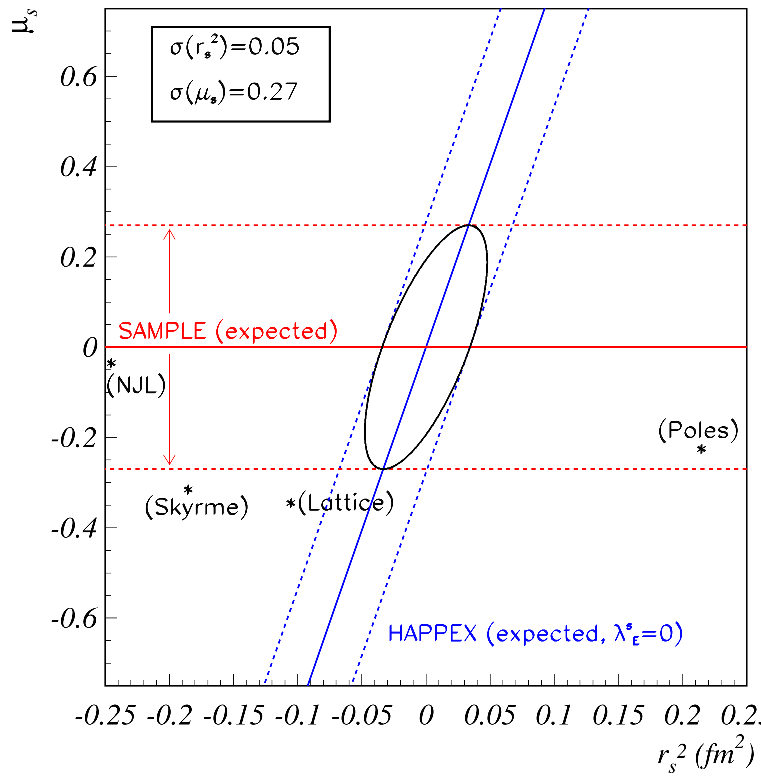
- **Leading non zero moments:**

$$\mu_s = G_M^s(0) \quad , \quad \rho_s = \frac{dG_E^s}{d\tau} = -\frac{2}{3} M_p^2 \langle r_s^2 \rangle - \mu_s \quad , \quad \langle r_s^2 \rangle = -6 \frac{dF_1^s}{dQ^2}$$

Models predictions vary widely in magnitude:

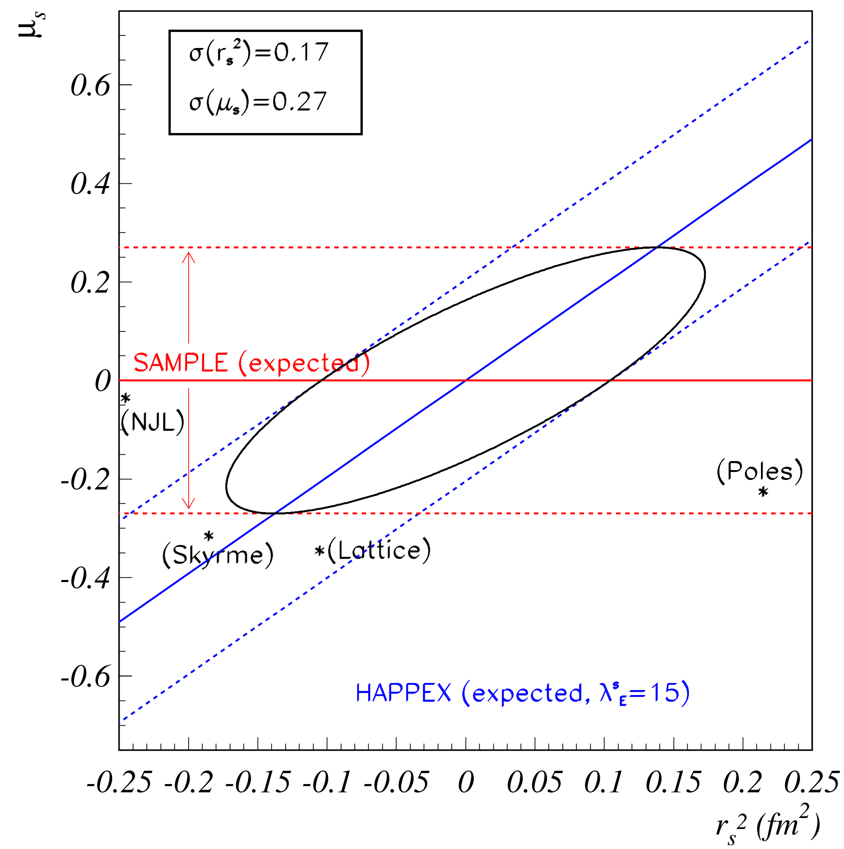
$$\boxed{\begin{aligned} r_s^2 &= -0.19 \to 0.21\, fm^2 \\ \mu_s &= -0.4 \to 0.03 \mu_N \end{aligned}}$$

SAMPLE + HAPPEX



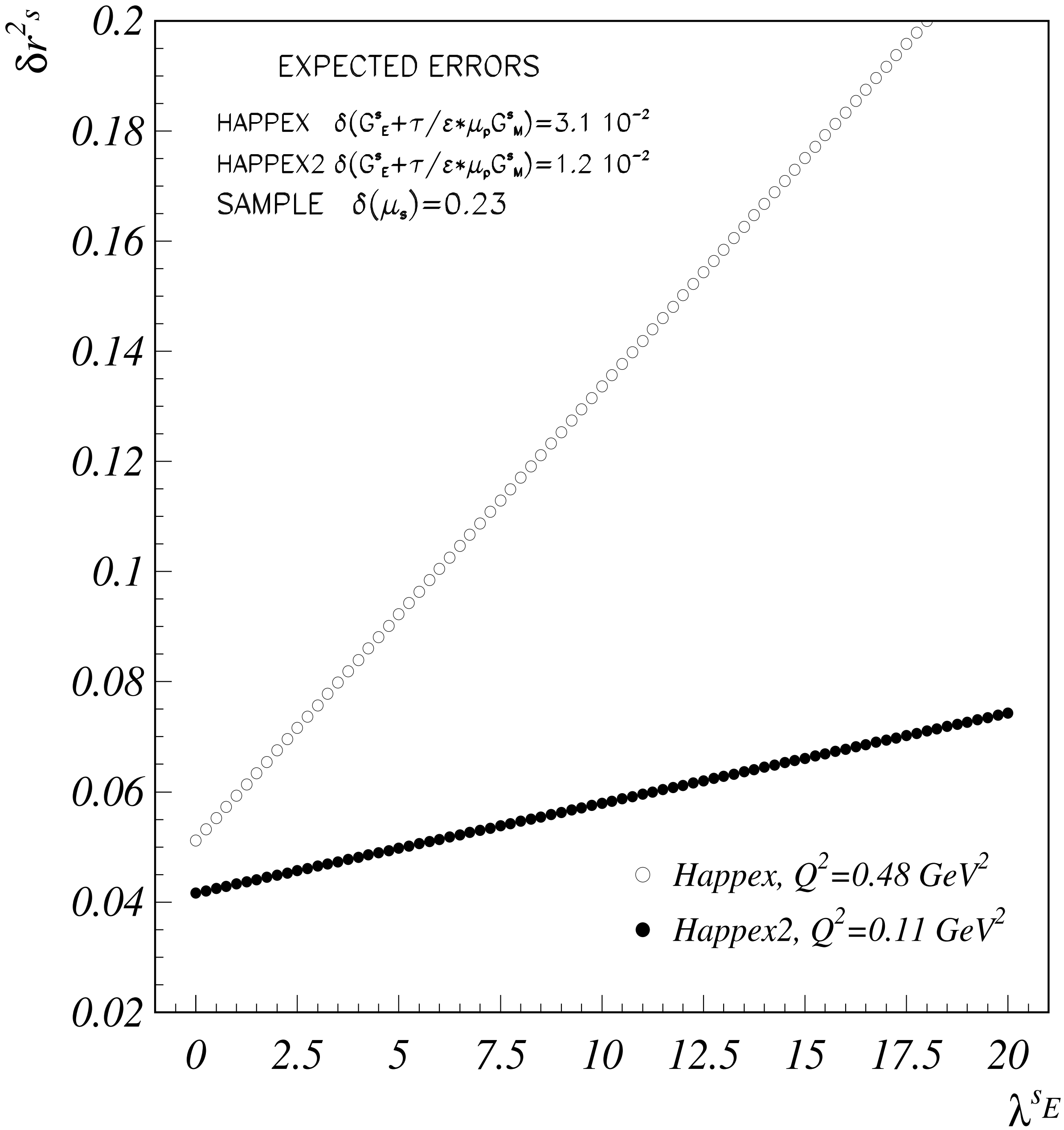
Galster's Parametrization:

$$G_E^s = \frac{\rho_s \tau G_D}{1+\lambda_E^s \tau} \quad , \quad G_M^s = \frac{\mu_s G_D}{1+\lambda_M^s \tau}$$



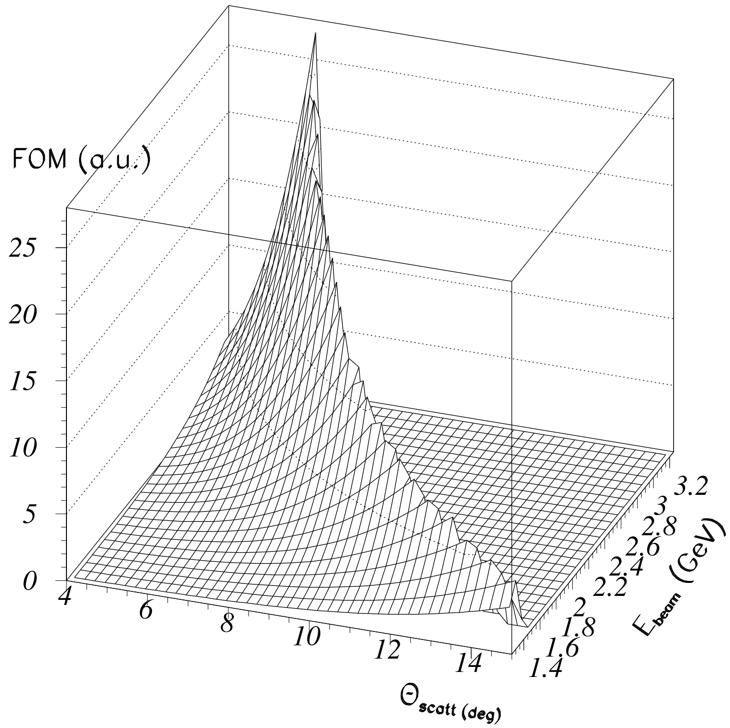
→ **Measurement at low Q^2**

Measurement at low Q^2



→ **Small sensitivity to Q^2 dependence**

Kinematics



I = 100 μA, P_e= 75%

$$\langle Q^2 \rangle = 0.11 GeV^2$$

$$\left\langle \frac{d\sigma}{d\Omega} \right\rangle = 44.5 \mu b \cdot sr^{-1}$$

HRS + Septum: $\Delta\Omega = 2 \times 3.57 msr$

Counting rate: $2 \times 63.5 MHz$

$$E = 3.2 GeV \quad \langle \Theta \rangle = 5.93°$$

$$A_{LR} = -1.63 ppm$$

$\frac{\delta A}{A} = 4.6\%$ **stat /700h**

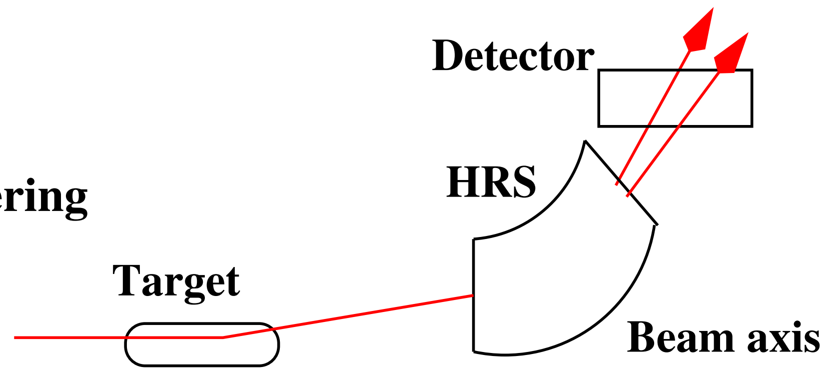
Measurement at low Q^2

HAPPEX technology

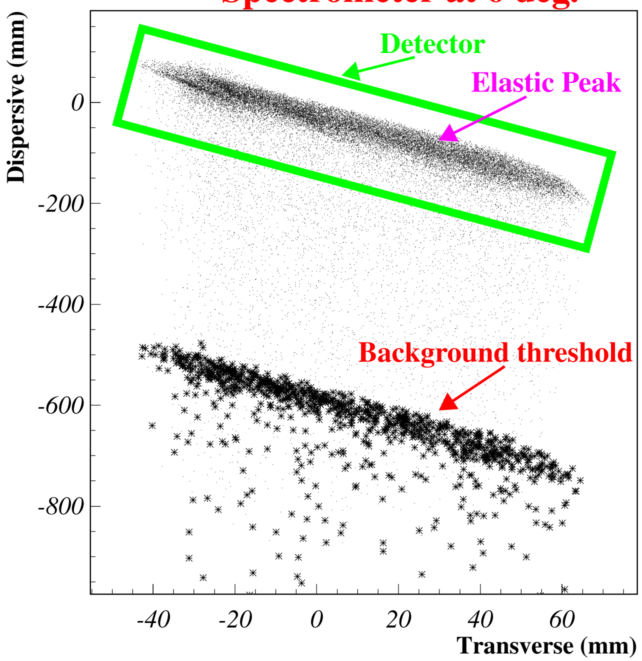
* High luminosity * HRS

* Control of the systematics:

Intensity feed back, beam dithering



Spectrometer at 6 deg.



* Focal plane detector

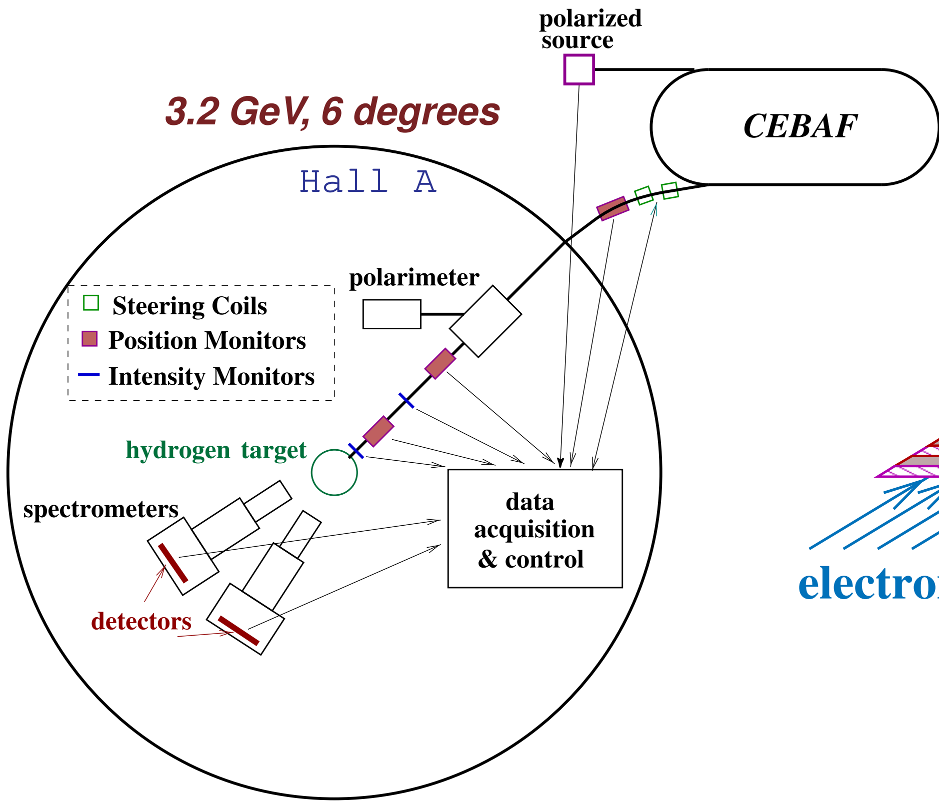
* Integrated high rate

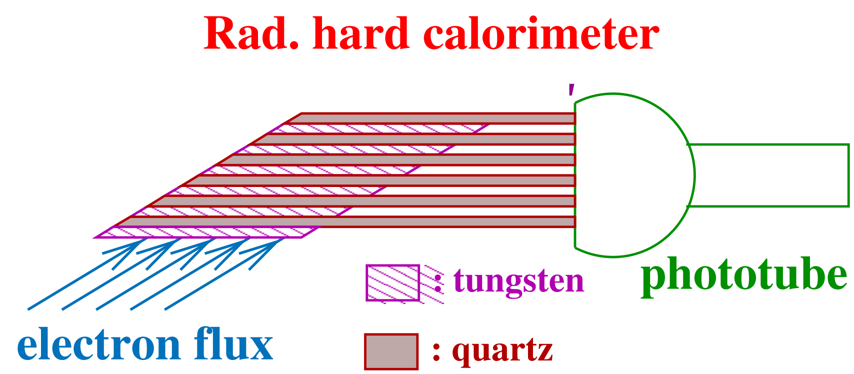
Already achieved:

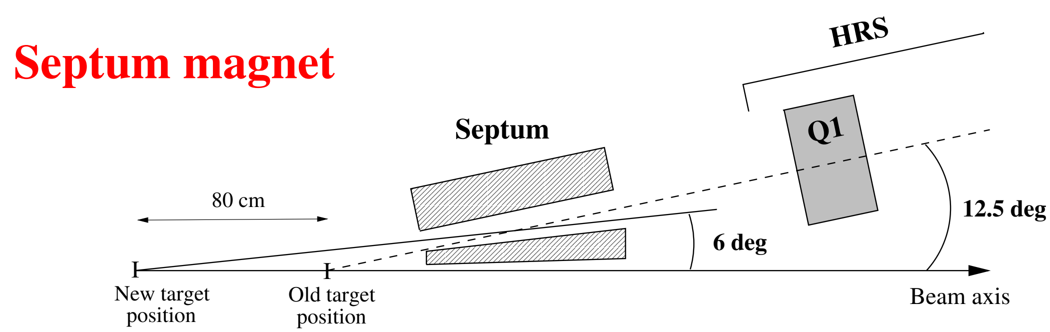
$$A_{raw} = -5.64 \pm 0.75(stat) \pm 0.04(syst)\, ppm$$

HAPPEX, published

"Table-top" experiment



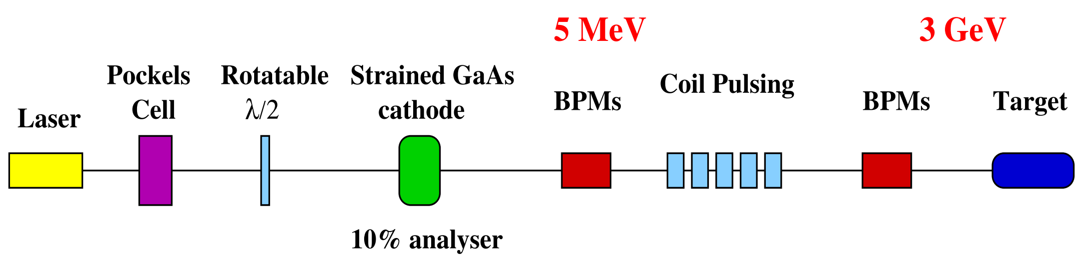




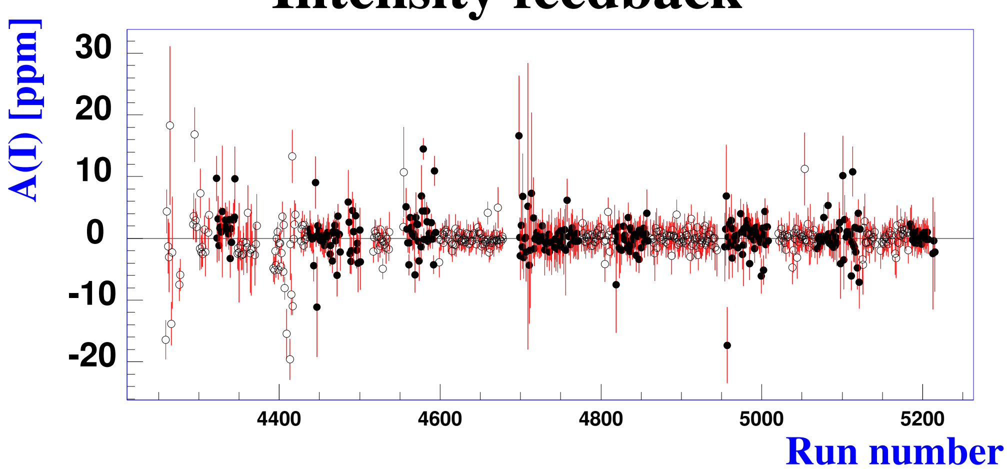
Systematics

What has been achieved for HAPPEX

Charge asymmetry

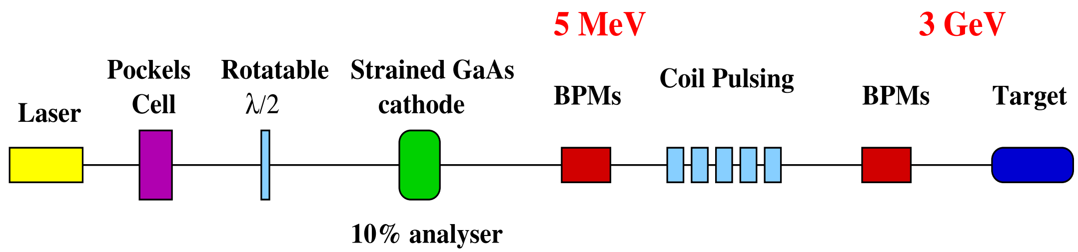


Intensity feedback



$\rightarrow$ $\boxed{A_I < 5\times10^{-7}}$ **Already fine !**

Systematics

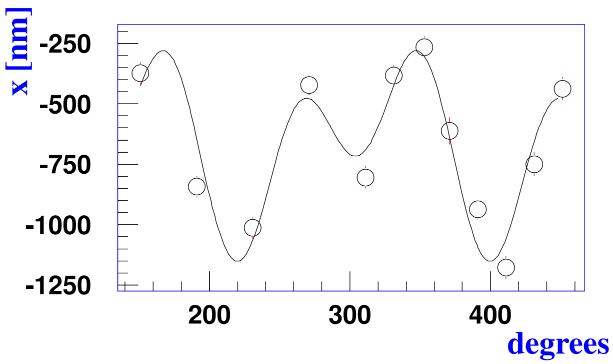


Position differences

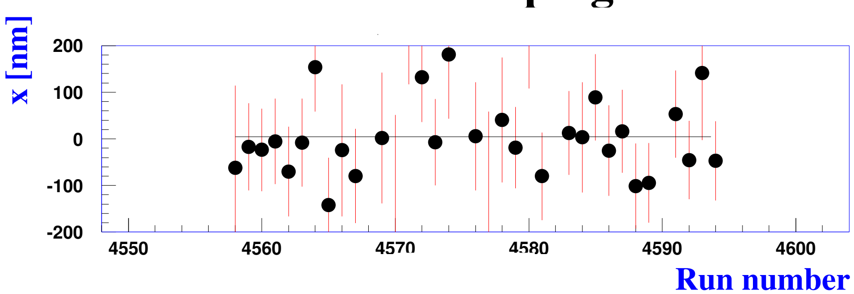
Happex: 20 nm → 0.15 ppm correction

Our goal: 5nm → negligeable systematics

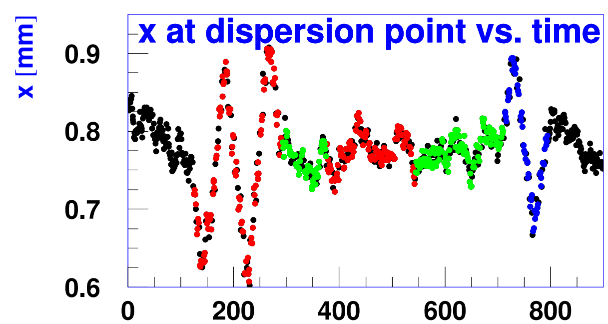
λ/2 vs Xbpm at 5 MeV



Transverse damping at 3GeV



Coil Pulsing



Normalization

- **Polarimetry**

  Moller already at 3%.

  Compton expected to reach 2%.

- **Q^2 determination**

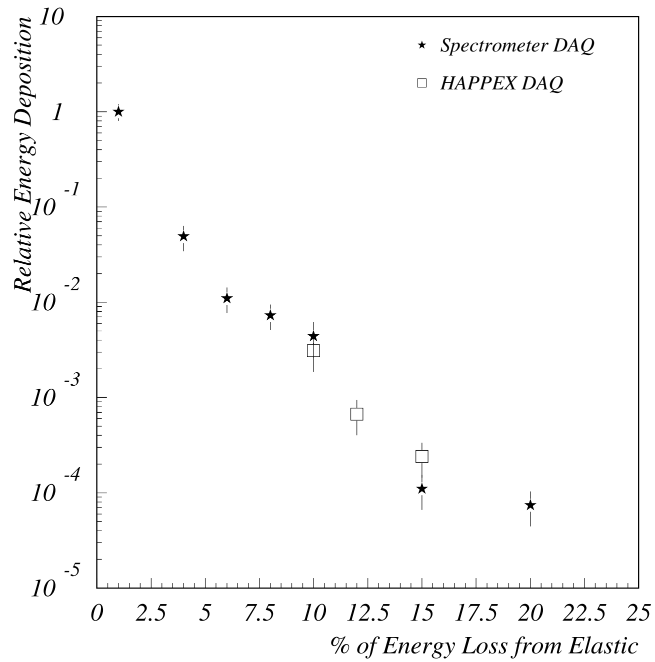
  $$\frac{\delta Q^2}{Q^2} \sim 2 \times \frac{\delta\Theta}{\Theta}$$

  Accurate enough

- **Background**

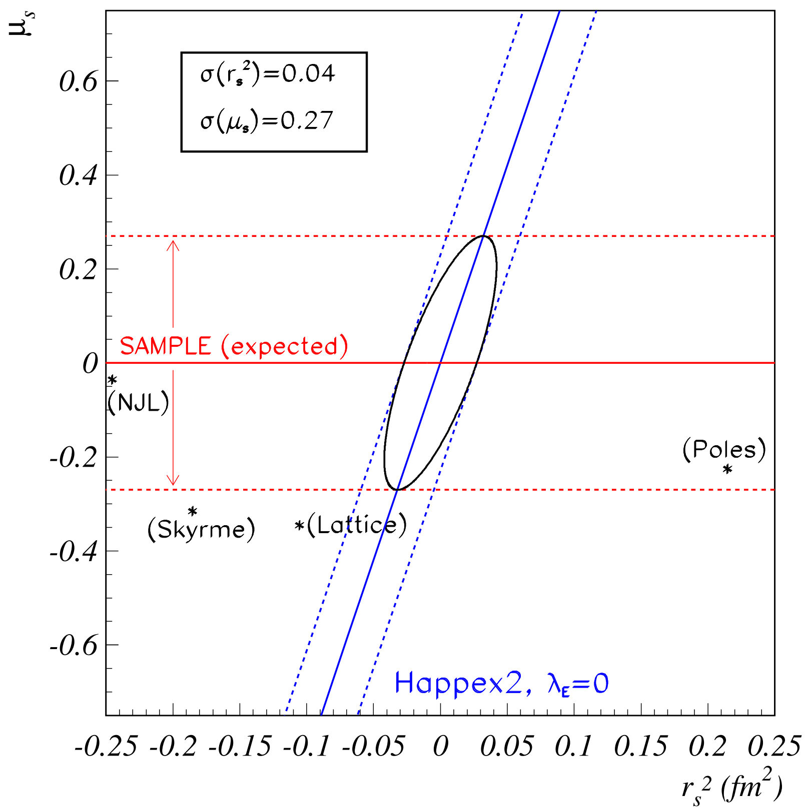
  * Quasi-elastic in end-caps
  * Pole-tip scattering
  * Rescattering of inelastic events

Dipole scan: HAPPEX data at 12 deg.



Error Budget

Source	$\delta A^{PV}/A^{PV}$	$\delta(\rho_s+\mu_p\mu_s)$
Statistics	**4.6 %**	**0.267**
Polarimetry	**2.0 %**	**0.116**
Background	**0.9 %**	**0.052**
Q^2	**0.6 %**	**0.035**
Rad. Corrections	**1.0 %**	**0.058**
Subtotal	**5.2 %**	**0.303**
G_E^n	**(1.4) 4.8%**	**(0.081) 0.278**
Total	**(5.4) 7.1%**	**(0.314) 0.411**



Powerful constraint on the charge radius $\Delta r_s^2 = 0.04\, fm^2$

Summary

Apparatus:

Standard Hall A equipment

HAPPEX DAQ.

Septum magnets

Radiation hard detector

Beam requests:

Current 100 μA

Polarization 75%

30 days

$$\left.\frac{\Delta A}{A}\right|_{Exp} = 4.6(stat) \oplus 2.5(syst) \oplus 1.4(ff)\ \%$$