Fitting for proton charge radius

Xuefei Yan

Sep 20 2017

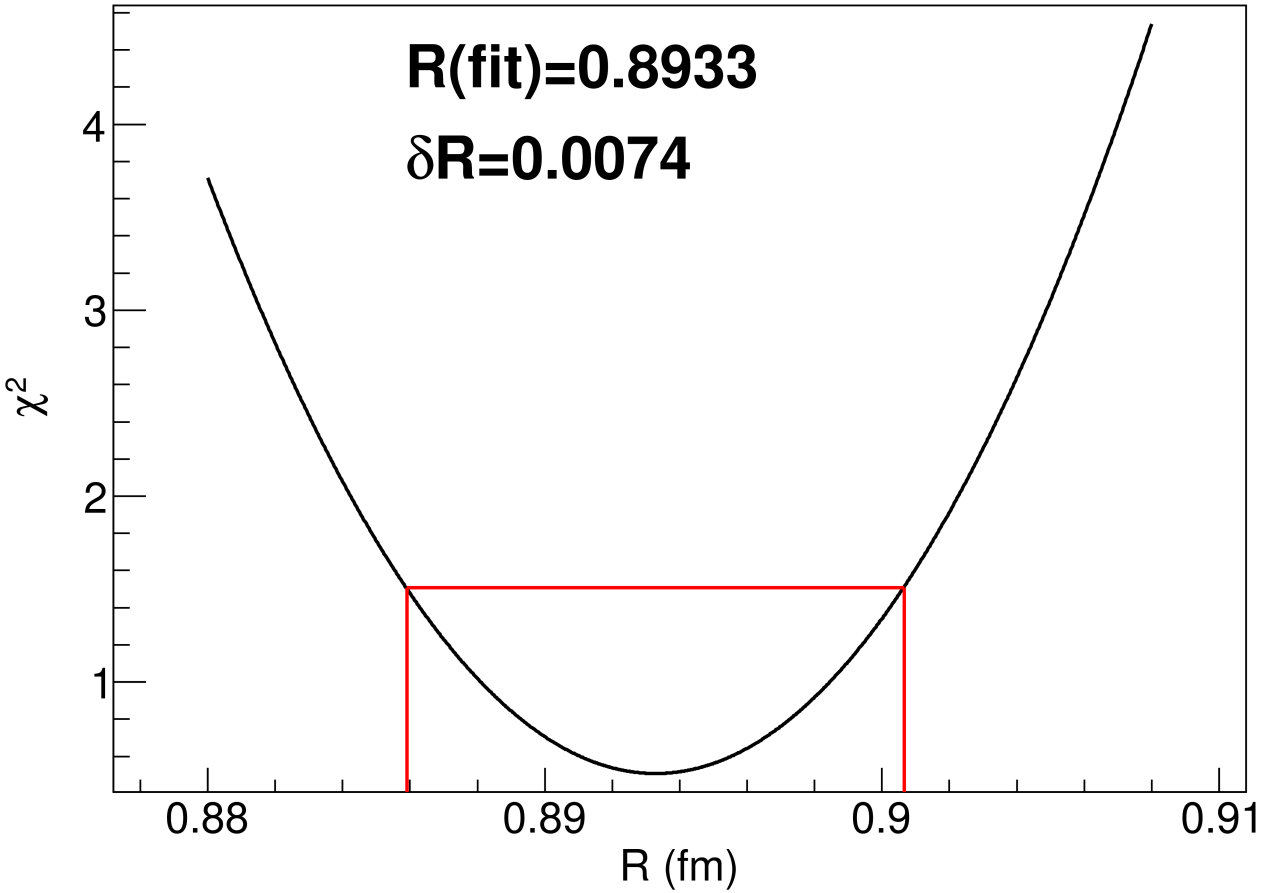
Progress

- Checked Ingo Sick's claim about PRad fitting uncertainty
  - Sick: including higher-power terms in GE expansion when fitting will dramatically increase uncertainty of R (larger than said in proposal)
    - Sick's uncertainty result of R comes from assuming $\langle r^4 \rangle$ as a free parameter, and can take + or – values (if assume + value only, R fitting uncertainty reduce by ~30%)
    - Sick's claim was based on fake data points: from $0.1 < Q < 0.7$ fm^{-1} ($3.9\times10^{-4} < Q^2 < 0.02$ GeV^2), 16 points of GE with 0.002 total uncertainty (at each data point): real PRad data should be better, need input from Weizhi Xiong, et al. to check
- Flexible fitting programs made for everyone to run
  - Root graphical fit (~same as Chao Peng's old ones), Minimizer fit (similar to Xuefei Yan's SIDIS cross section fit), fit based on χ^2 distribution plot
  - Multiple models/functional forms for GE fitting

Check Sick's claim: fitting uncertainty

- Sick's results based on 16-point fake data
  - Fitting with terms up to Q^2: dR=0.0075 fm
  - Fitting with terms up to Q^4 dR=0.027 fm [he did not say in the email that he added an additional parameter, but in his paper PRC 95, 012501(R) (2017) he studied the fitting results with various $\langle r^{2n} \rangle$ moments as free parameters]
- Xuefei Yan's result based on 16 point fake data (Root graphical fit & minimizer gave ~same result: double checked)
  - Fake data generated by model with R=0.8768 fm, up to 2^{nd} power of Q
  - Fitting with terms up to Q^2: dR=0.0069 fm
  - Fitting with terms up to Q^4: dR=0.0245 fm ($\langle r^4 \rangle$ as a free parameter, + or -)
  - Fitting with terms up to Q^4: dR=0.0166 fm ($\langle r^4 \rangle$ as a free parameter, > 0)
  - Fitting with terms up to Q^4: dR=0.0073 fm (assume dipole charge distribution)

Triple check example: χ^2 distribution plot



- Fitting with terms up to Q^4, assuming dipole charge distribution: $\langle r^4 \rangle = 2.5\ R^4$ (one-para fitting)
- Conventionally one-sigma uncertainty same as $\delta\chi^2 = 1$ contour
- Left & right red box edge: $\delta\chi^2 = 1$
- Result ~same as ROOT graphical fit & Minimizer fit

- Two-parameter χ^2 distribution plot will be a 2D contour

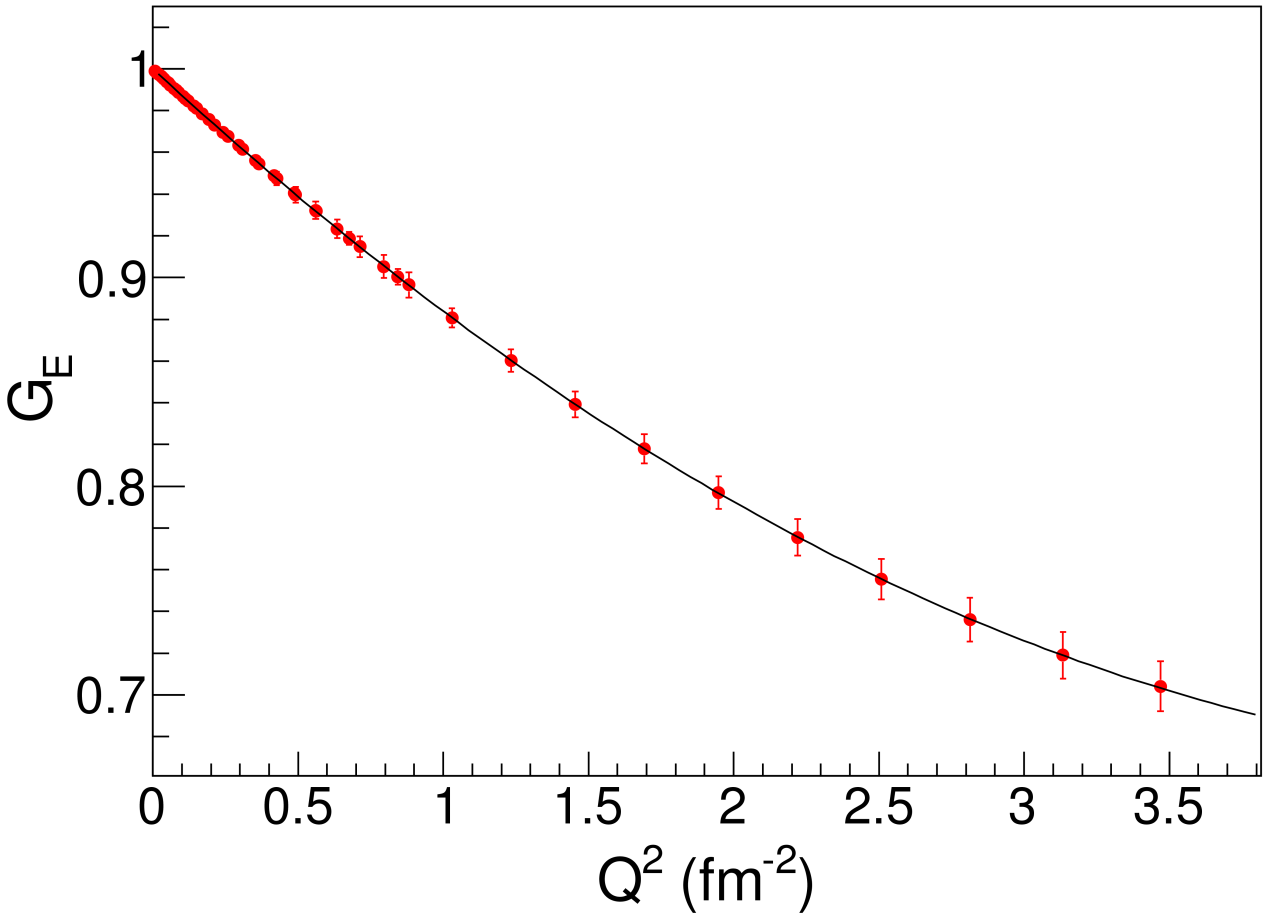
- Note: 16-point fake data generated by GE functional form up to 2nd order of Q, with R=0.8768 fm
  - Q^4 term (positive coefficient) will make R(fit) ≠ R(gen, up to Q^2): Q^2 term has negative coefficient

PRad people can use multiple methods of fitting and compare results

- Polynomial of n terms (Q^{2n}) fitting with 1 parameter (R): assuming dipole, monopole or Gaussian shape of proton charge distribution; program made using formla in [Z. Physik A 275, 29 (1975), PRC 93, 055207 (2016)]
  - Model dependent, but one can use many models
- Polynomial of n terms (Q^{2n}) fitting with n parameters ($<r^{2n}>$): model independent, but will give larger fitting uncertainty for R
  - Model independent
- Other types: we can discuss

- Code on Duke server: /var/phy/project/mepg/xy33/PRad_fit/
- Code on ifarm: /work/hallb/prad/xy/PRad_fit/

Test: fitting Chao Peng's old Q^2 vs. GE table with functional forms up to Q^4 term



Charge distribution assumption (1-para)	χ^2	R
Dipole	0.3064	0.8781±0.0039 fm
Monopole	52.87	0.8933±0.0040 fm
Gaussian	37.93	0.8587±0.0036 fm

Type	χ^2	R
2nd power, 1-para	240.38	0.8196±0.0032 fm
4th power, 2-para	0.3062	0.8782±0.0047 fm

- Simulation based on dipole model of GE
- Only statistical uncertainties included in these fits

To do

- Give the fitting program(s) a GE vs. Q2 with (total) uncertainties, they will give the results in 1 click