Radius extraction 2

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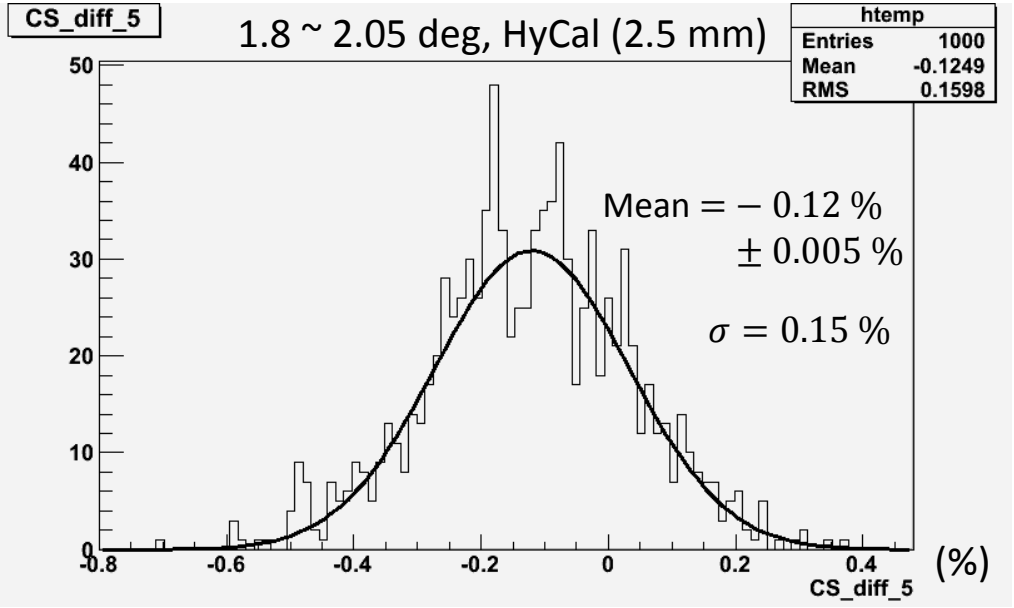
Simulation

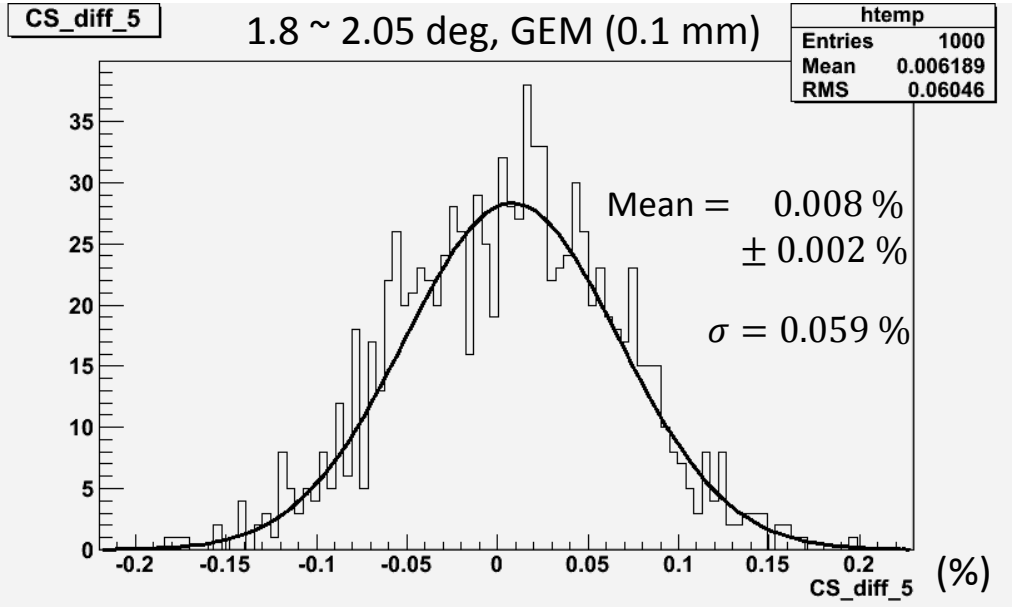
- Monte-Carlo simulation, ep and Möller events at Born level are generated (3 days for 1.1 GeV, 12 days for 2.2 GeV)
- Target position uncertainty is included (Gaussian distribution, 1 cm sigma)
- Position and energy recorded on the detectors are smeared with the detectors' resolutions
  - HyCal, 2.5 mm for central part, 5.5 mm for lead glass part
  - GEM, 0.1 mm
  - Fiber, 0.3 mm and 0.6 mm
- Cross-sections are calculated according to the single-arm selection method

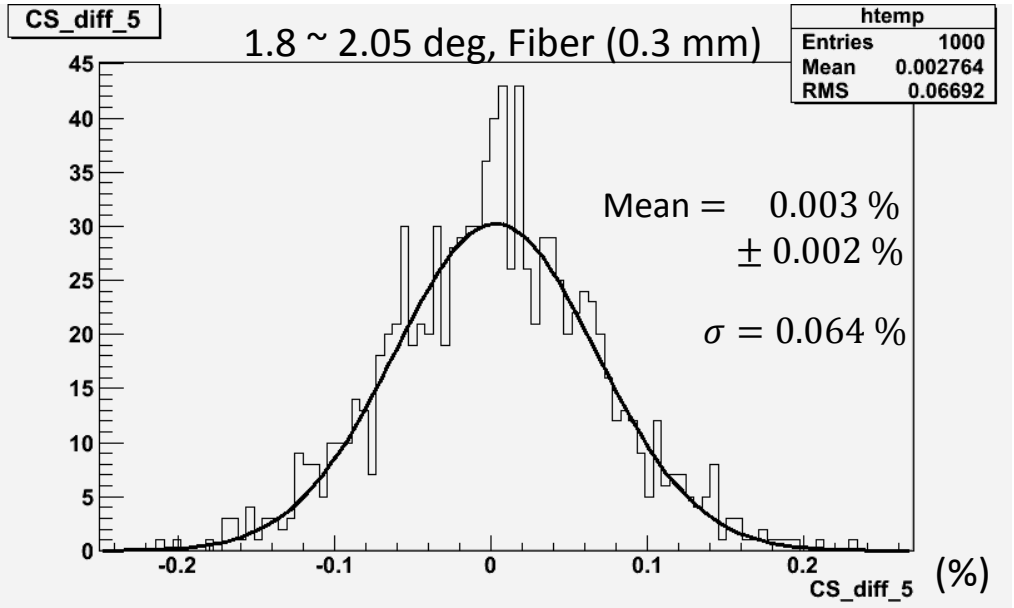
$$\left(\frac{d\sigma}{d\Omega}\right)_{ep}\left(Q_i^2\right) = \left[\frac{N_{\mathrm{exp}}^{\mathrm{yield}}\left(ep \rightarrow ep \text{ in } \theta_i \pm \Delta\theta\right)}{N_{\mathrm{exp}}^{\mathrm{yield}}\left(e^-e^- \rightarrow e^-e^-\right)}\right]\left(\frac{d\sigma}{d\Omega}\right)_{e^-e^-}$$

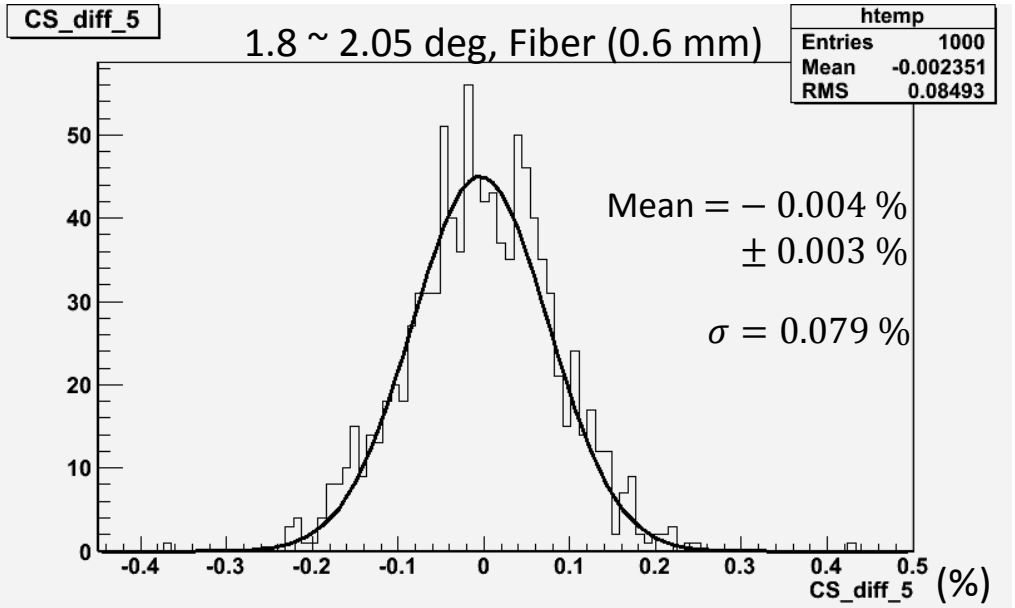
- The factor of $\frac{N_{\mathrm{exp}}^{\mathrm{yield}}\left(ep \rightarrow ep \text{ in } \theta_i \pm \Delta\theta\right)}{N_{\mathrm{exp}}^{\mathrm{yield}}\left(e^-e^- \rightarrow e^-e^-\right)}$ changes due to the angular resolution of detectors and the different distributions of ep and Möller events, this results in the uncertainties of cross-sections

Uncertainty of the measured cross sections in the simulation

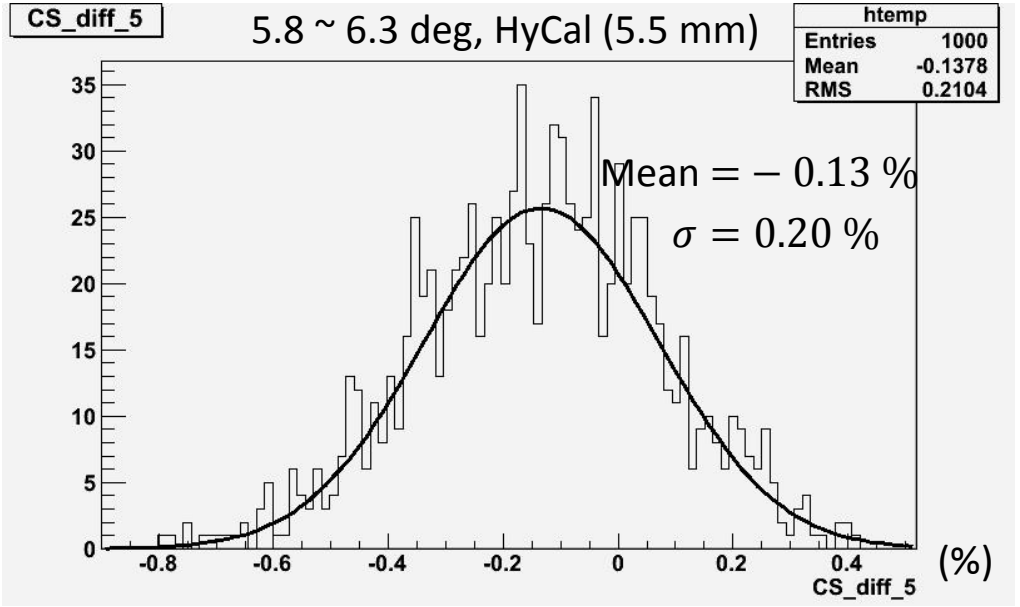


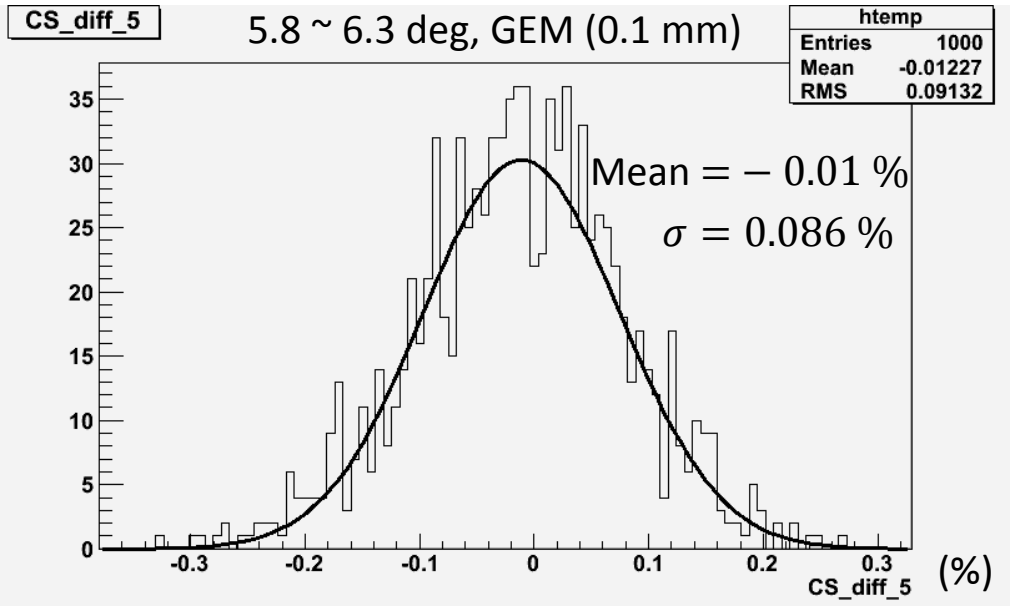


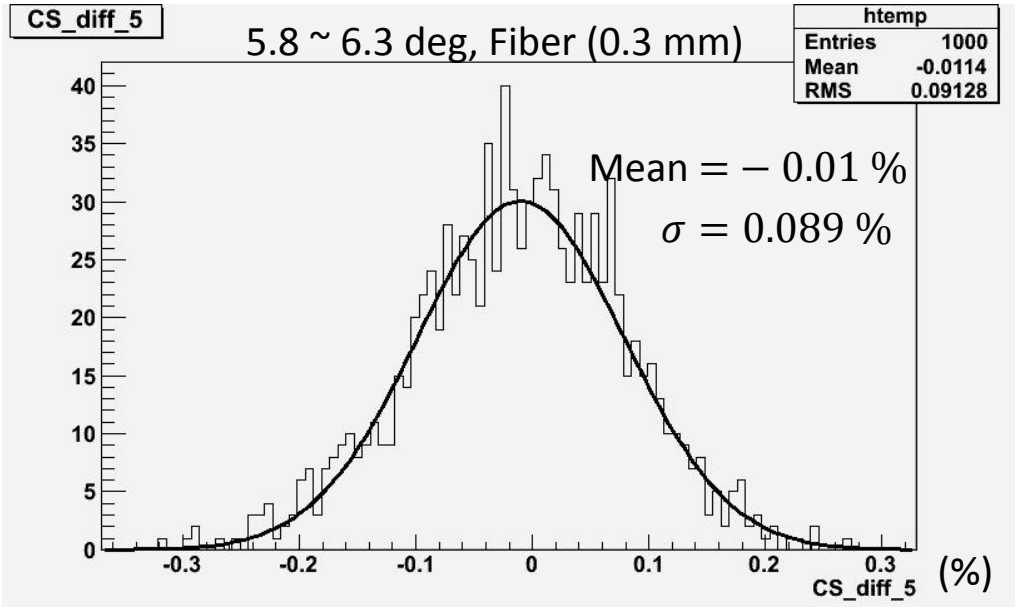


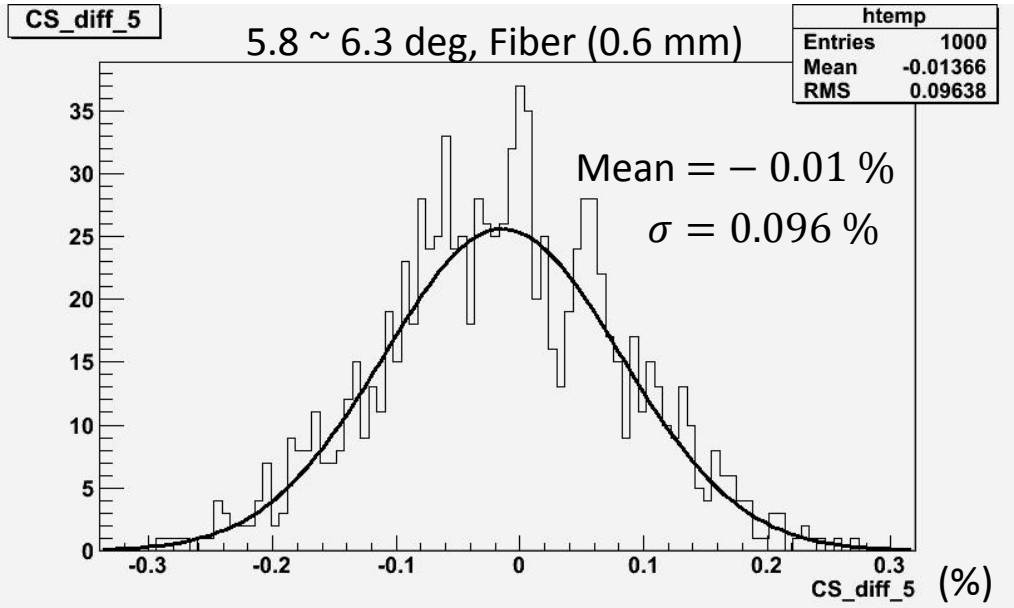


Uncertainty of the measured cross sections in the simulation









Simulation

- G_E uncertainties are determined by

$$G_E(Q_i^2) = \sqrt{-\frac{\tau}{\epsilon}G_M^2(Q_i^2) + \frac{1+\tau}{\sigma_M}\frac{d\sigma}{d\Omega}(Q_i^2)}$$

$$\delta G_E = \frac{1}{2}\frac{\sqrt{\left(-2\frac{\tau}{\epsilon}G_M\delta G_M\right)^2 + \left(\frac{1+\tau}{\sigma_M}\delta\sigma\right)^2}}{G_E}$$

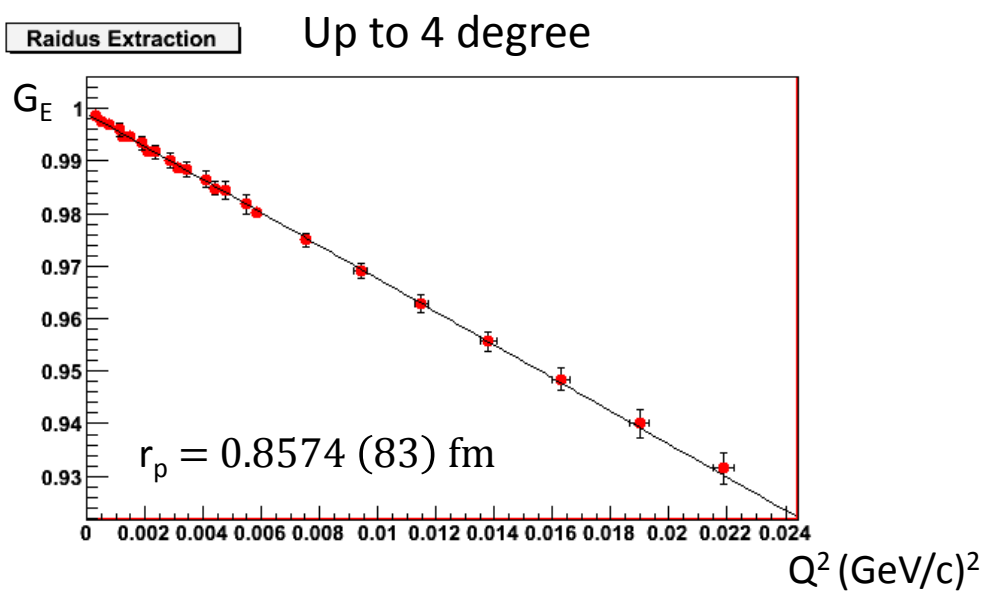
δGM is assumed to be 1%, and $\delta\sigma$ is obtained by the simulation

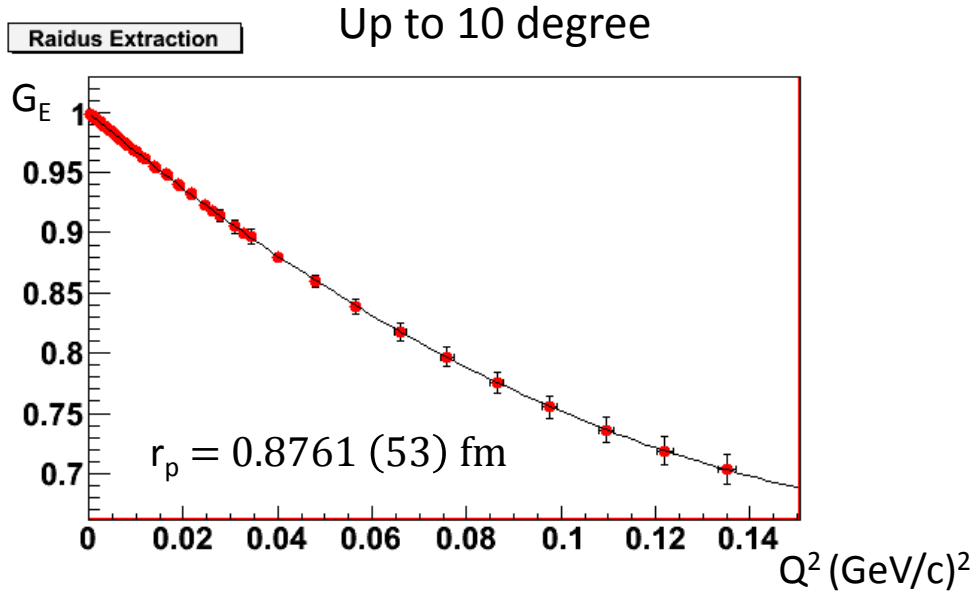
- Q^2 is determined by angle and incident beam energy, resolution of Q^2 is directly assumed to be the error bar of Q_i^2 (From A. Gramolin's presentation)

$$\sigma_{Q^2} = \sqrt{\left(\frac{\partial Q^2}{\partial E}\right)^2\sigma_E^2 + \left(\frac{\partial Q^2}{\partial \theta}\right)^2\sigma_\theta^2}$$

Radius fittings for HyCal only

- r_p = 0.8768 fm in the code, dipole form for G_E (up to the term of $\langle r^4 \rangle$) and G_M
- Uncertainties are from the simulation (presentation on 02/07/2014), statistical uncertainty $1/\sqrt{N}$ for the cross-sections is included
- Central part (up to 4 degree) fittings are updated and shown in the left plots
- Linear fit for the central part (left), dipole fit for the whole angle range (right)





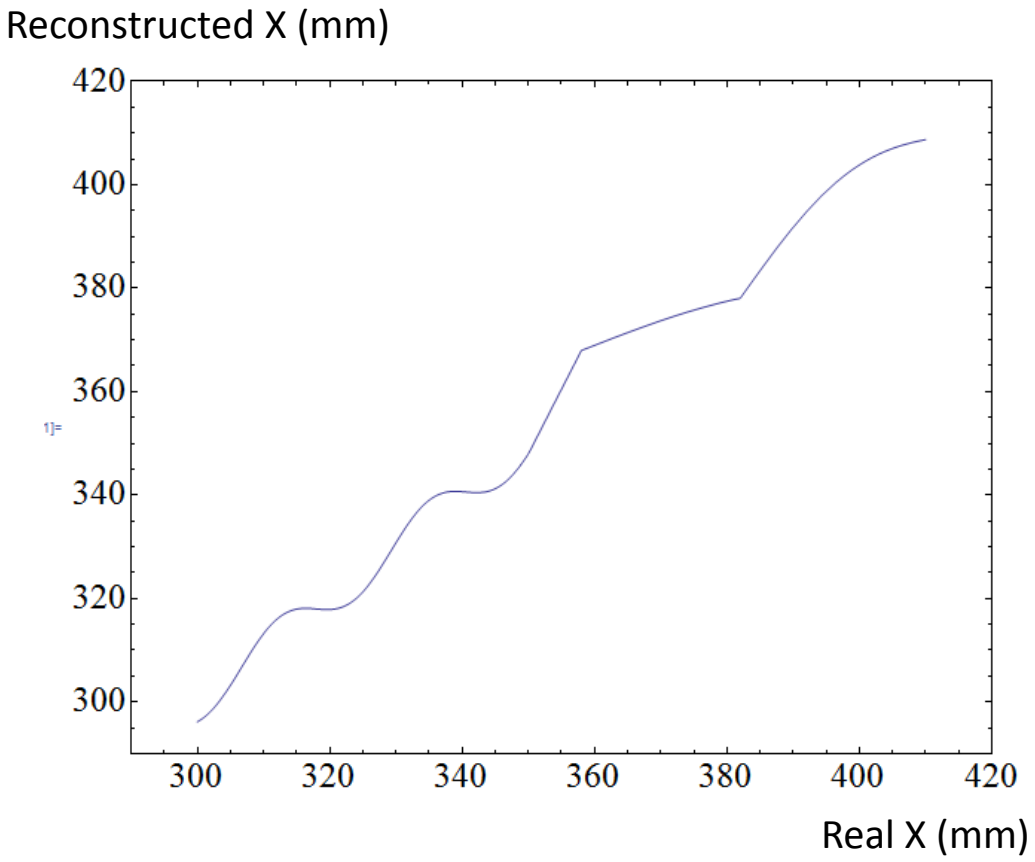
Biased position reconstruction of HyCal

- Biased position reconstruction of HyCal are considered as a systematical error in the new simulation

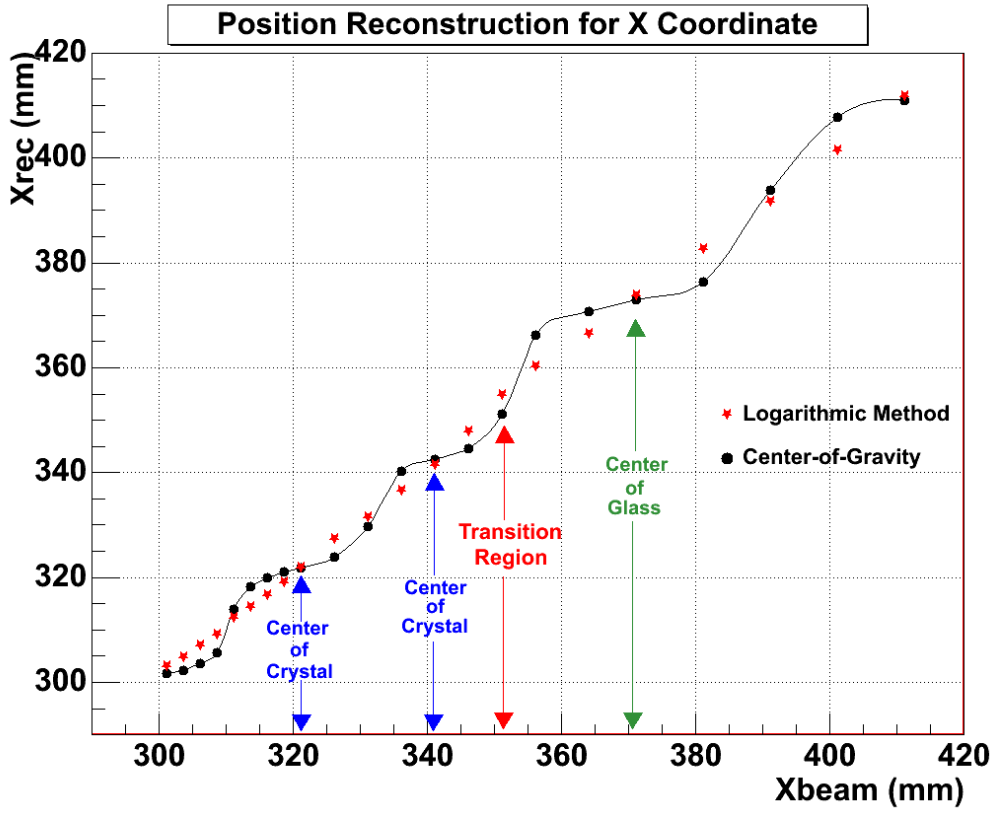
- A piecewise function with the form $A_i + Bisin\left(\frac{x-x_{0i}}{C_i}\right) + Di(x - x_{0i})$ is used to approximately describe the biased position reconstruction in the code

- The recorded position is biased by this function, and thus the uncertainties of the cross-sections for the single-arm selection method are obtained by the simulation

Biased position reconstruction of HyCal



Piecewise function used in the simulation



Reconstruction data from the presentation*

* A. Gasparian, PRad Collaboration Meeting, 12/2013.

Uncertainties of the cross-sections

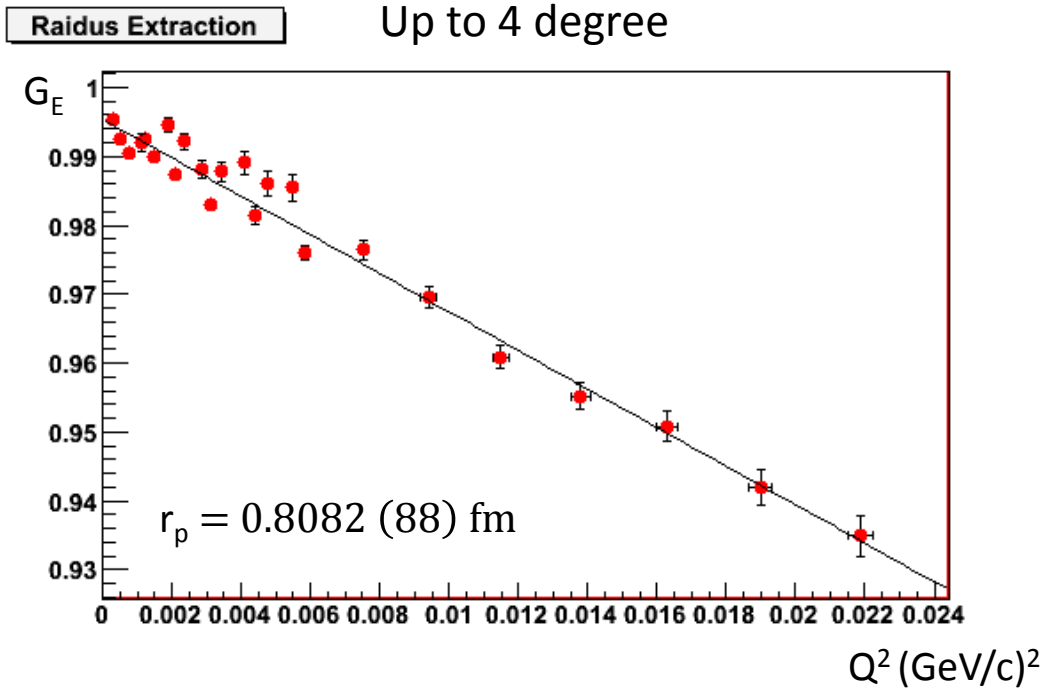
- The biased position will change the ratio of $\frac{N_{ep}}{N_{ee}}$ in each bin, because of the different distributions of ep and Möller events.
- The change of acceptance ratio results in a systematical error of the cross-sections
- The uncertainties of the cross-sections at 1.1 GeV are shown in the tables

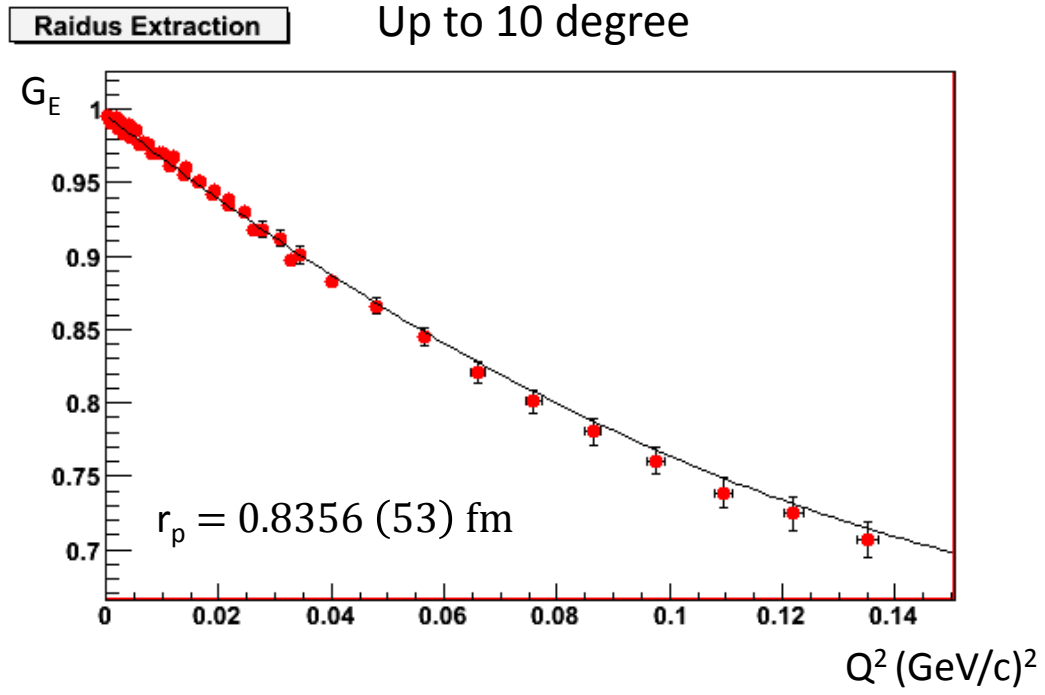
Angle bin	Syst. uncertainty
0.80 – 1.05	-0.70 %
1.05 – 1.30	-1.16 %
1.30 – 1.55	-1.38 %
1.55 – 1.80	-0.88 %
1.80 – 2.05	-1.03 %
2.05 – 2.30	0.15 %
2.30 – 2.55	-0.04 %
2.55 – 2.80	-0.49 %
2.80 – 3.05	-0.19 %
3.05 – 3.30	0.47 %
3.30 – 3.55	0.31 %
3.55 – 3.80	0.65 %

Angle bin	Syst. uncertainty
3.80 – 4.30	-0.16 %
4.30 – 4.80	-0.63 %
4.80 – 5.30	0.35 %
5.30 – 5.80	1.29 %
5.80 – 6.30	1.31 %
6.30 – 6.80	0.73 %
6.80 – 7.30	1.10 %
7.30 – 7.80	1.22 %
7.80 – 8.30	1.36 %
8.30 – 8.80	0.74 %
8.80 – 9.30	1.50 %
9.30 – 9.80	0.95 %

Updated fittings

- Including these systematical errors, the new fitting results for HyCal are shown in the plots
- The extracted radius is far away from the input of the code (r_p = 0.8768 fm)

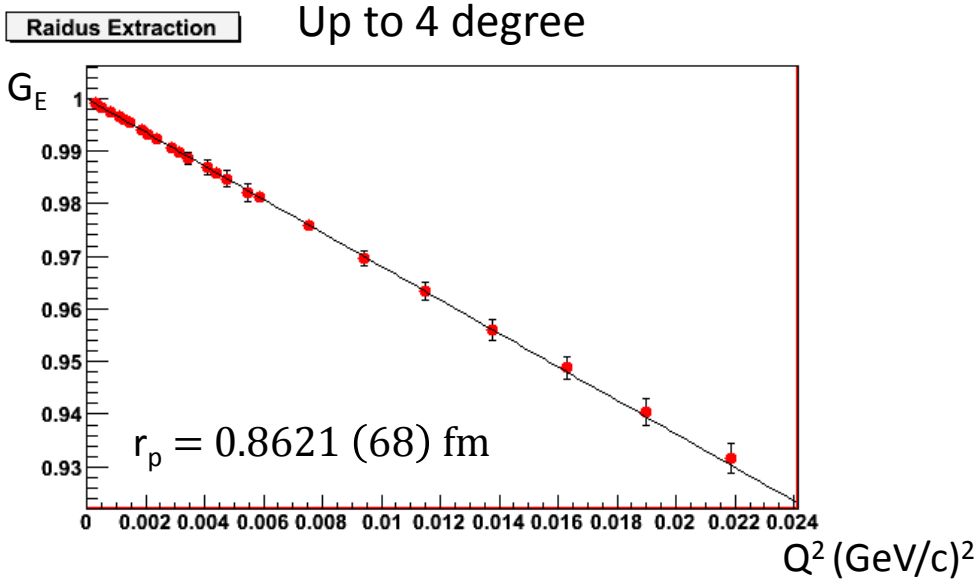




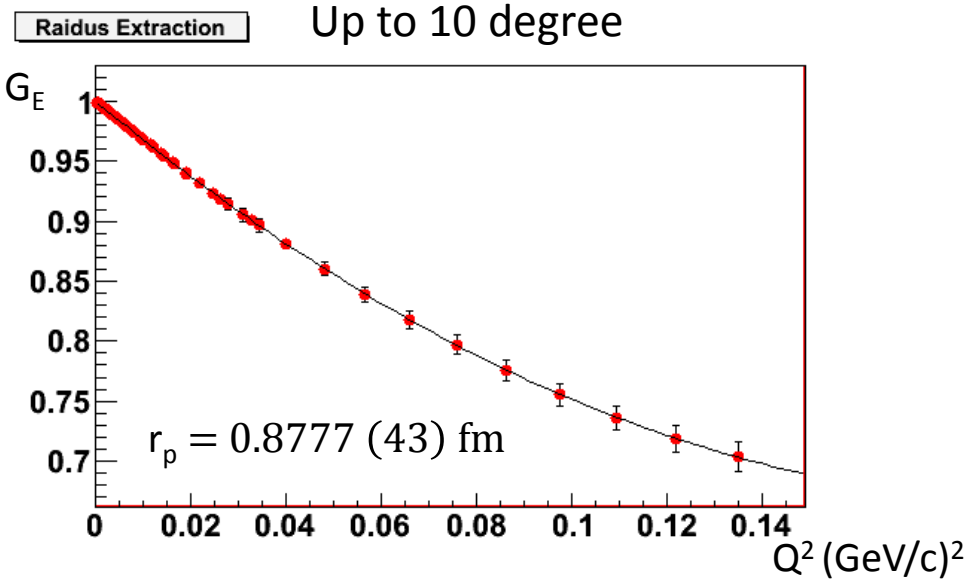
Additional position detectors

- Additional position detectors are used instead of HyCal, so the biased position reconstruction is avoided, the fitting result is close to the input
- GEM, resolution 0.1 mm
- r_p = 0.8768 fm in the code. Uncertainties are from the simulation (presentation on 02/07/2014), statistical uncertainty $1/\sqrt{N}$ for the cross-sections is included

Up to 4 degree

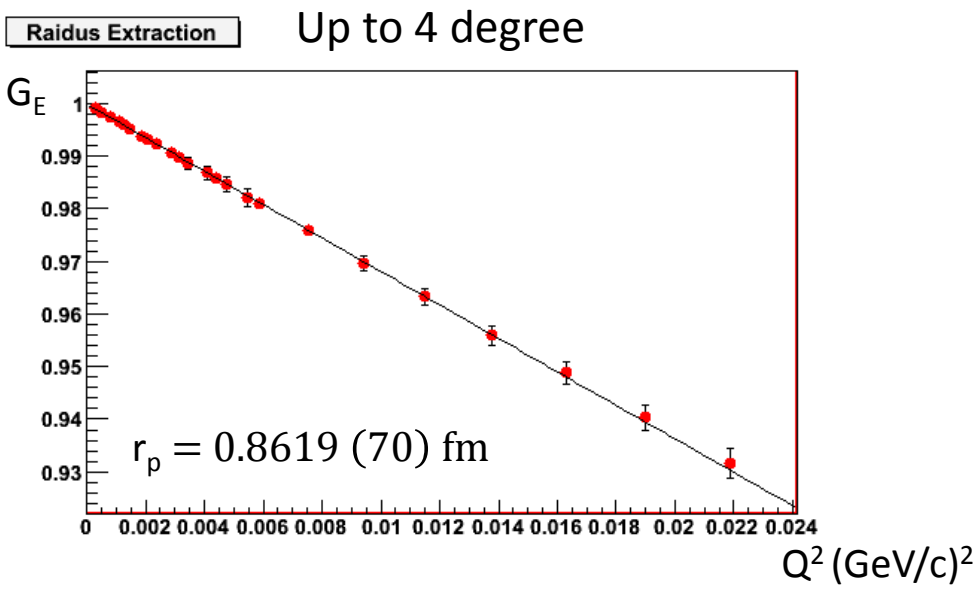


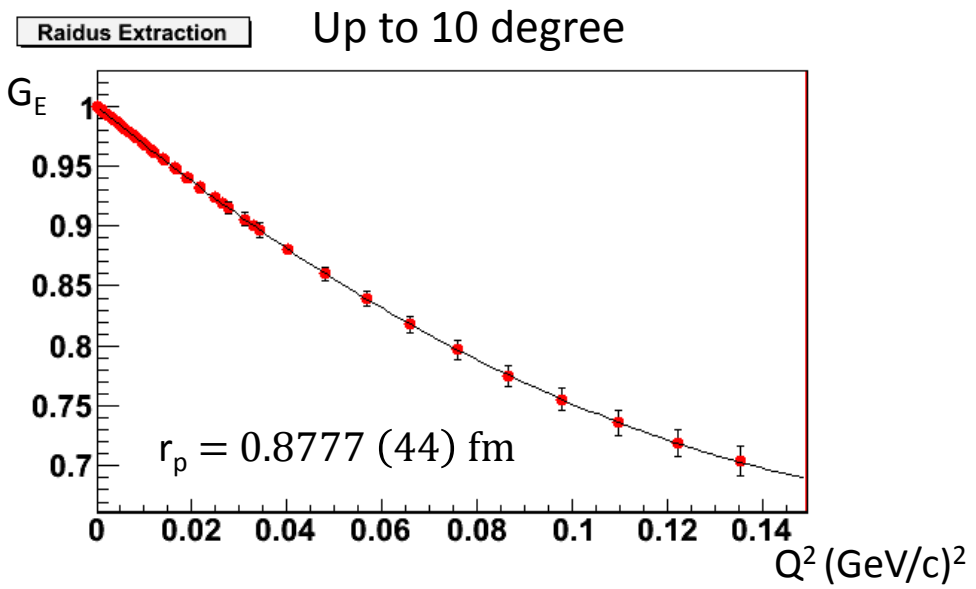
Up to 10 degree



Additional position detectors

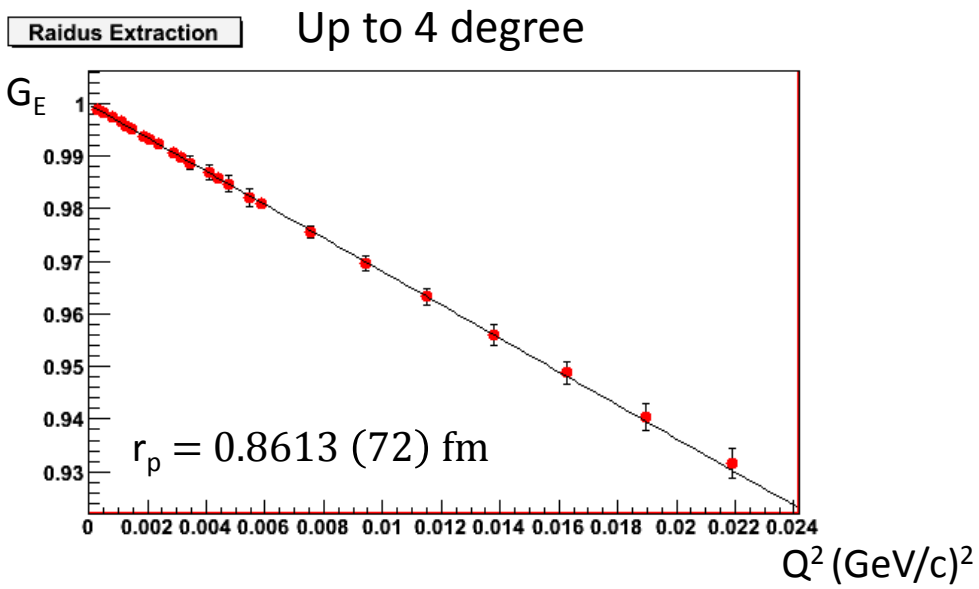
- Fiber, resolution 0.3 mm
- r_p = 0.8768 fm in the code

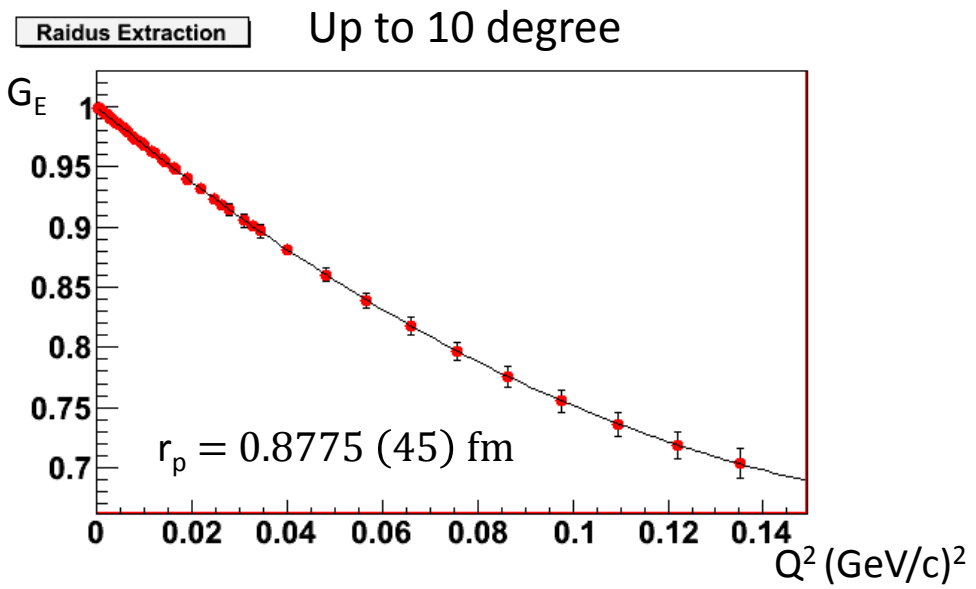




Additional position detectors

- Fiber, resolution 0.6 mm
- r_p = 0.8768 fm in the code





Summary

- Linear fittings for the central part always obtain a smaller radius
- The biased position reconstruction of HyCal results in a huge systematical error of the extracted radius
- Additional position detectors will remove the systematical error from biased position reconstruction
- The improvement between the additional position detectors (from 0.1 mm resolution to 0.6 mm resolution) is not significant

To do

- Need to implement other systematical errors into the study

- Central Q^2 determination (Q_i^2 for each bin)will probably be improved by binning, the study is ongoing